ELECTRICAL ENGINEERING

JULY 1945

54

UBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Roller-Smith Unit Substation
11,500/2,300/450/230 volts

Engineered as a Unit

with One Responsibility

ROLLER-SMITH UNIT SUBSTATIONS

**UNIT
SUBSTATION SAVINGS**

SAVES CONSTRUCTION COSTS

Weatherproof

SAVES INSTALLATION COSTS

Factory Assembled

SAVES INVESTMENT

New Units added easily

SAVES SPACE AND MATERIALS

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STANDARD AND PRECISION ELECTRICAL INSTRUMENTS • AIRCRAFT INSTRUMENTS • SWITCHGEAR •
AIR AND OIL CIRCUIT BREAKERS • ROTARY SWITCHES • RELAYS • PRECISION BALANCES

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Do you have a TOUGH winding problem?

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Take advantage of Belden Wire Engineering Service. It cuts your over-all winding costs.

*** BELDEN POLYVAR**

is available in magnet wire Types F, HF, TF, and QF, either plain or in combination with textile or paper insulations. Try Belden Polyvar on your tough winding jobs.

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Belden Magnet Wires

NATURAL AND SYNTHETIC ENAMEL AND TEXTILE INSULATIONS

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices, 33 West 39th Street, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925.

July 1945, Vol. 64, No. 7. Number of copies of this issue 27,000

FOR ALL ELECTRICAL APPLICATIONS--

BH EXTRA FLEXIBLE FIBERGLAS SLEEVING

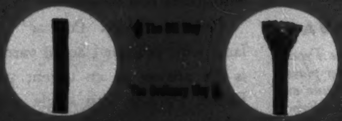
WON'T HARDEN, CRACK OR ROT!

SNUB TEST

Proves BH Non-Fray Feature

Make this test yourself. Tap a piece of ordinary saturated sleeving on your desk top and see how easily it frays. Then do the same with BH Extra Flexible Fiberglas Sleeving. It only fuzzes a little—doesn't break down—doesn't fray.

THE RESULT



BH EXTRA FLEXIBLE FIBERGLAS SLEEVING

2 WAYS BETTER

NON-FRAYING • NON-STIFFENING

WHY give a few cents worth of electrical insulation a chance to be the weak link in *your* product? Use BH *Extra Flexible* Fiberglas Sleeving—the *one* insulation with *all* these advantages:

It is *permanently* non-fraying, non-stiffening and non-burning, by virtue of the exclusive BH process. It will not dry out, crack or rot, retaining its original unusual resistance to high and low temperatures, moisture, oil, grease and chemicals *indefinitely*.

If you want an all-purpose sleeving that simplifies assembly and maintenance and gives longer maximum protection, standardize on BH *Extra Flexible* Fiberglas Sleeving. Available in all standard colors and sizes from ⅝" to No. 20, inclusive. Write for free samples today and compare by actual test!

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Direct contact with heat up to 1200°F does not harm BH Special Treated Fiberglas Sleeving, the non-burning, unsaturated, flexible-as-string sleeving that stays supple and won't fray when cut. Made in natural color only—all standard sizes. Get this *extra* protection now and keep customers' temper cool, too!

ALL BH PRODUCTS AVAILABLE IN STANDARD 36" LENGTHS and 500-FT. COILS

BH PRODUCTS

ALSO SLOW-BURNING [illegible] MAGNETO TUBING • [illegible] TUBING • SATURATED SLEEVING • A.S.T.M. [illegible]

BENTLEY, HARRIS MANUFACTURING CO.

Dept. C, Conshohocken, Penna.

ALL BRANCHES OF THE ELECTRICAL INDUSTRY benefit from adequate wiring. Get behind this activity, gearing your selling efforts to it. (This message appears before owners, management and architects.)

blacked out

by a 2% investment in electrical distribution

The right plans today can prevent electrical "growing pains" tomorrow. Adequate wiring today can make old or new buildings ready for load upswings tomorrow. Seldom before has the selection of a power distribution system been such a key decision — important far beyond the two to ten percent of the plant investment which the system represents.

Seldom before has so much effective help been available in making the right choice and avoiding the profit-paralyzing consequences of the wrong selection. One example is the new book "Electric Power Distribution for Industrial Plants" published by the American Institute of Electrical Engineers. (It's obtainable for $1.00 from the Institute's offices at 33 West 39th St., New York 18, N. Y.) An entire chapter on wires and cables recognizes their key importance in providing plenty of power for plenty of years. For further help in selecting wires and cables, go over your plans with an engineer of The Okonite Company, Passaic, New Jersey or The Hazard Insulated Wire Works Division, Wilkes-Barre, Pa.

ELECTRIC POWER DISTRIBUTION for INDUSTRIAL PLANTS

SEE CHAPTER SIX "WIRES AND CABLES"

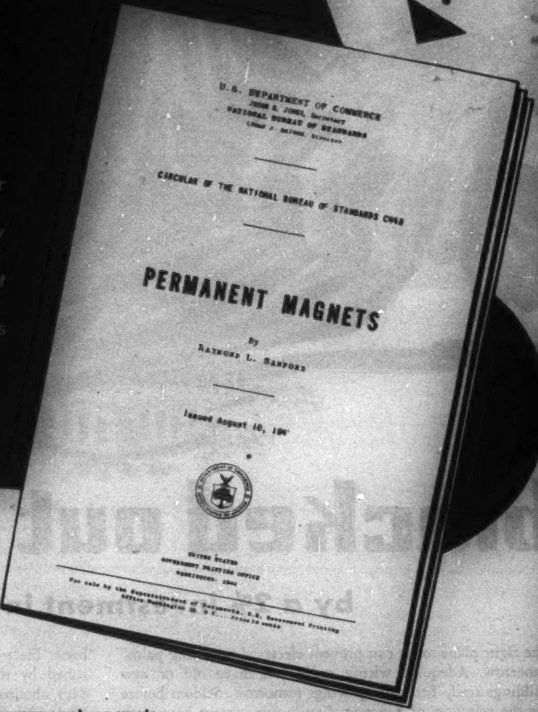
HAZARD

insulated wires and cables

4079

YOURS!

Just write us, on your letterhead, for your copy of this valuable booklet on permanent magnets



U.S. DEPARTMENT OF COMMERCE
JESSE H. JONES, Secretary
NATIONAL BUREAU OF STANDARDS

CIRCULAR OF THE NATIONAL BUREAU OF STANDARDS C448

PERMANENT MAGNETS

By
RAYMOND L. SANFORD

Issued August 10, 194[illegible]

● As a service to industry, The Arnold Engineering Company is "lending a hand" in the distribution of what Arnold engineers believe to be a very informative study on the subject of permanent magnets.

This 39-page book of permanent magnet theory, design data and references was published by the government. Arnold is pleased to make it available to you free of charge and without obligation. Write for it today!

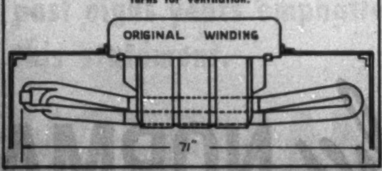
THE ARNOLD ENGINEERING COMPANY
147 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS
Specialists in the Manufacture of ALNICO PERMANENT MAGNETS

National Re-Design Cuts Operating Temperature

Above is photo of [illegible] KVA, 300 RPM, 11,000 Volt Sy[illegible] Condenser rewound by National Electric Coil Company to provide lower operating temperatures at increased loads. Drawings below show original winding (left), which operated with 100% load at 57.2° C., and re-designed winding (right), now operating with 104.6% load at 48.3° C.

I[illegible] often possible to re-design the windings of rotating electrical equipment to provide satisfactory operation under changed conditions and requirements. National has solved thousands of problems involving higher ambient temperature, increased load, moisture, chemical attack, abrasion and just about every other electrical ailment. The re-design job by National illustrated and described here is typical. Let us shoulder *your* troubles. Call the nearest National field engineer, or write us, for quick action.

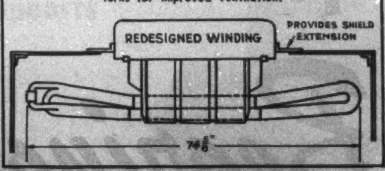
Original winding provided only 1/8" space between end turns for ventilation.



57.2° C. *Average Temp.* (*100% Load*)

48.3° C. *Average Temp.* (*104.6% Load*)

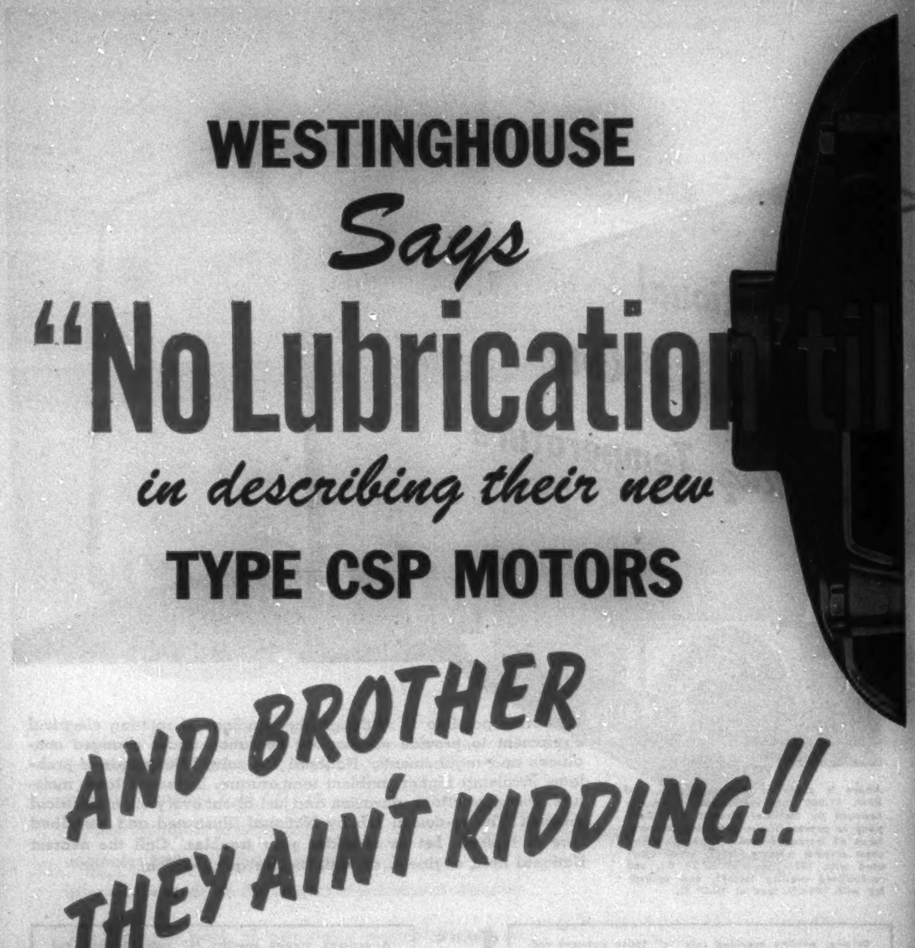
Re-designed winding provides 3/8" space between end turns for improved ventilation.



NATIONAL ELECTRIC COIL COMPANY

COLUMBUS 16, OHIO, U. S. A.

ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION—REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES



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Says

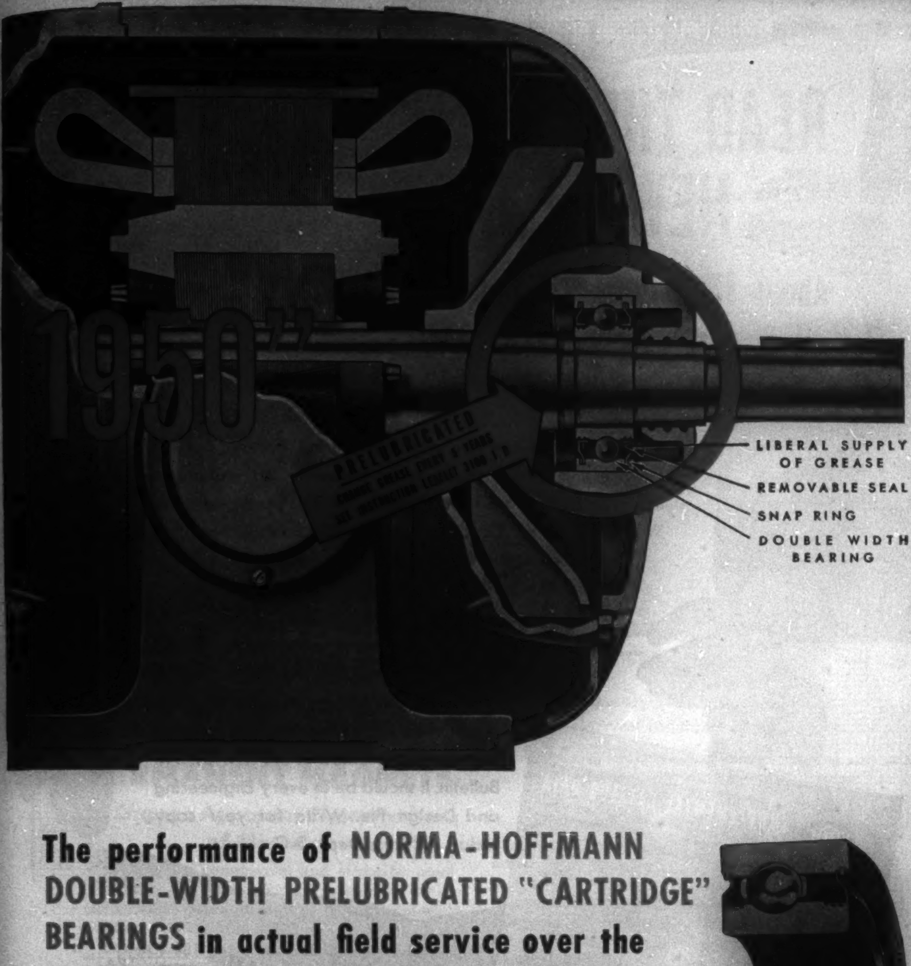
“No Lubrication 'til

in describing their new

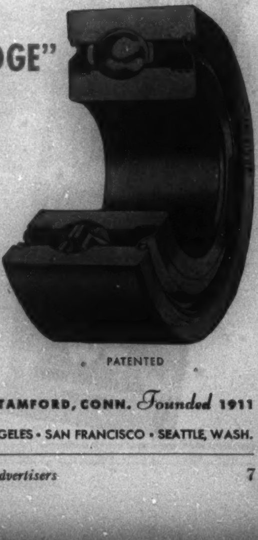
TYPE CSP MOTORS

AND BROTHER THEY AIN'T KIDDING!!

***Bearings by* NORMA**


1950"
PRELUBRICATED
LIBERAL SUPPLY OF GREASE
REMOVABLE SEAL
SNAP RING
DOUBLE WIDTH BEARING

The performance of NORMA-HOFFMANN DOUBLE-WIDTH PRELUBRICATED "CARTRIDGE" BEARINGS in actual field service over the past eight years emphatically supports this statement.



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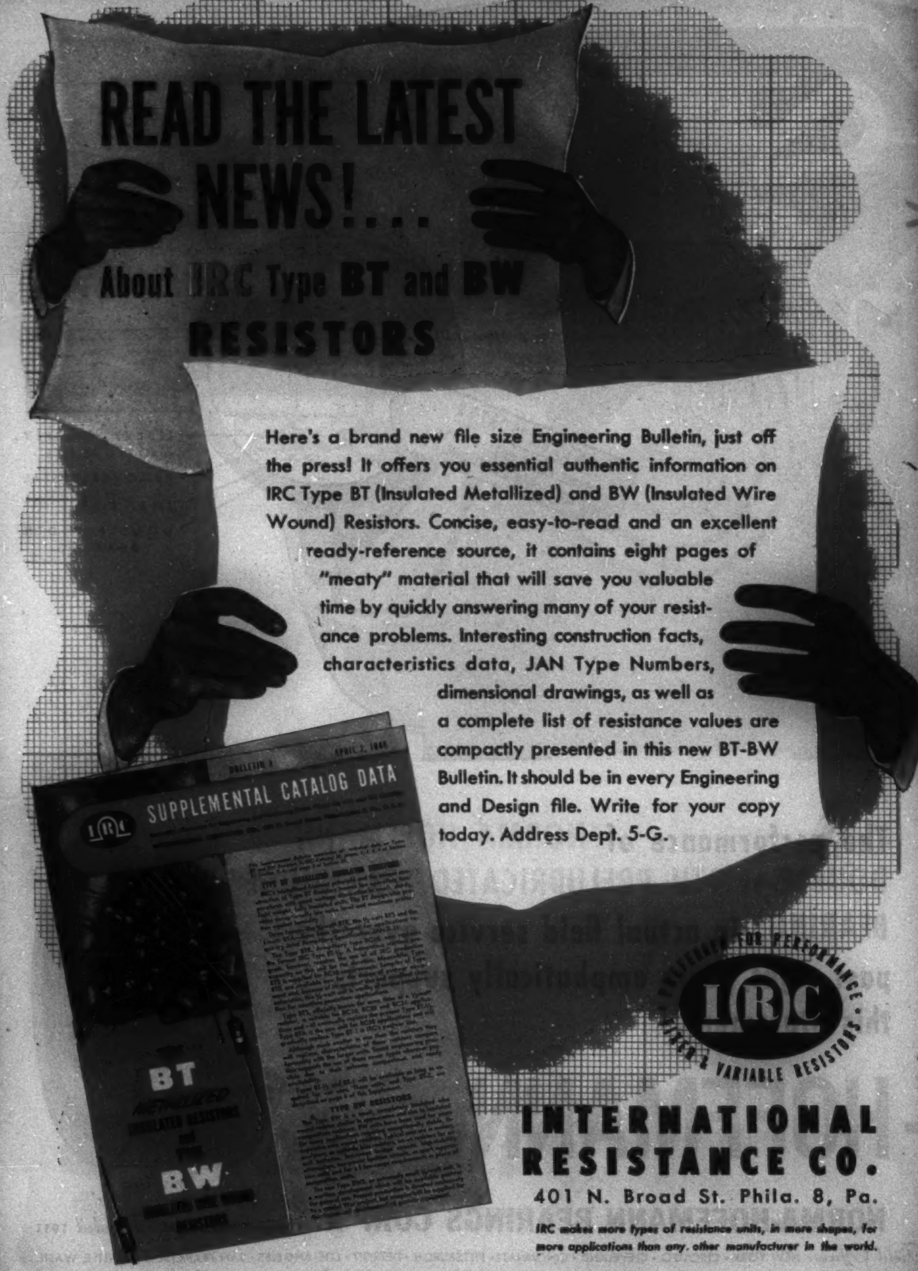
-HOFFMANN

NORMA-HOFFMANN BEARINGS CORP'N. STAMFORD, CONN. *Founded* 1911

Field Offices: NEW YORK • CHICAGO • CLEVELAND • CINCINNATI • PITTSBURGH • DETROIT • LOS ANGELES • SAN FRANCISCO • SEATTLE, WASH.


BULLETIN 4
APRIL 2, 1945
SUPPLEMENTAL CATALOG DATA
IRC
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BT
METALLIZED
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and
BW
RESISTORS

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Here's a brand new file size Engineering Bulletin, just off the press! It offers you essential authentic information on IRC Type BT (Insulated Metallized) and BW (Insulated Wire Wound) Resistors. Concise, easy-to-read and an excellent ready-reference source, it contains eight pages of "meaty" material that will save you valuable time by quickly answering many of your resistance problems. Interesting construction facts, characteristics data, JAN Type Numbers, dimensional drawings, as well as a complete list of resistance values are compactly presented in this new BT-BW Bulletin. It should be in every Engineering and Design file. Write for your copy today. Address Dept. 5-G.

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FIXED & VARIABLE RESISTORS

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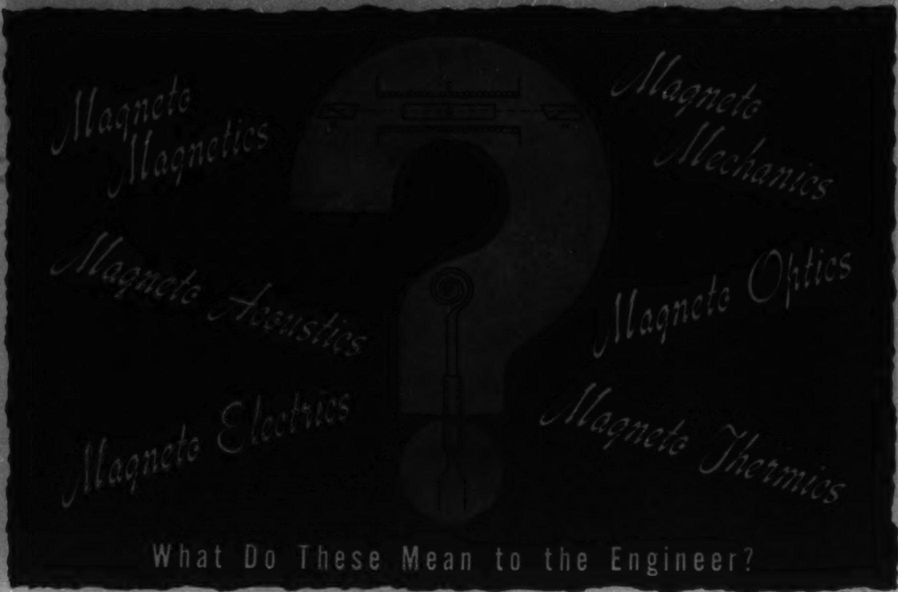
IRC makes more types of resistance units, in more shapes, for more applications than any other manufacturer in the world.

PERMANENT MAGNETS MAY DO IT BETTER



What Do These Mean to the Engineer?

(This is the fourth of four advertisements discussing the major functions of permanent magnets.)

THE LEAST KNOWN FUNCTION OF PERMANENT MAGNETS

To Change Apparent Characteristics of Materials

What are the commercial and scientific possibilities in the application of magnetism which changes the characteristics of certain materials whether gas, liquid or solid?

We know, for example, that the application of a magnetic field will cause the following changes:

IT WILL CHANGE

- *the apparent a.c. permeability of soft magnetic substances*
- *the normal hysteresis curve of magnetic materials*
- *the dimensions of nickel and some other metals*
- *the frequency of a tuning-fork*
- *the electrical resistance of bismuth*
- *the boiling point of some materials*
- *the rotation of polarized light through many materials*

These and kindred effects, which are known and are being investigated by physicists, may well lead to new fields for the application of permanent magnets. The potential uses of this little known property of magnetism have been scarcely touched industrially, although it has been employed in magneto stricture oscillators, in remote control indicators and, by the use of bismuth to determine field densities.

Our own research, based upon 35 years of specialization in the manufacture of permanent magnets, may help you to find some new means of achieving desired results. Write for consultation. Without obligation, send for copy of technical handbook: "Permanent Magnets Have Four Major Jobs."

★ THE INDIANA STEEL PRODUCTS COMPANY★

6 NORTH MICHIGAN AVENUE, CHICAGO 2, ILLINOIS

SPECIALISTS IN PERMANENT MAGNETS SINCE 1910

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PUT THE REINS OF *Load-Frequency Control* IN ANY HANDS YOU WISH

Economic Load Control
Tie Line " "
Flat Frequency Control
Telemetering, Recording, Totalizing of Load
Recording of Frequency

By means of L&N instruments, the distribution of electric load can be made to meet the specific needs of any power system, and regulation can be fully automatic, fully manual with complete information to guide the load dispatchers, or can occupy any position between fully automatic and fully manual.

Interconnections, multi-station systems, isolated stations of all sizes and even motor-generators are operating more economically because L&N load controllers, telemeters, recorders and totalizers are being used in the applications for which each is ideally suited.

Over eighteen millions of kva capacity are now under L&N automatic load-frequency control.

Additional millions are telemetered, recorded and totalized by L&N instruments, to guide system operators in allocation of load.

And practically every system which records frequency at all does so with L&N Recorders.

These installations offer a wealth of practical operating experience as a guide to improvement of load distribution under practically any specific circumstances.

Primary and Secondary Standard Instruments for LABORATORIES

The laboratories of most power systems use L&N instruments for some or all of the following purposes: Wattmeter calibration; instrument-transformer testing; pyrometer checking; measurement of temperature, insulation resistance, power factor, and many other conditions. We also supply the primary standards of resistance, capacitance, inductance and potential to support the accuracy of completely-assembled instruments.

Instrumentation For PRIME-MOVERS

There are several dozen points in the operation of prime movers at which L&N measurements or controls are commonly applied. Among them: Combustion, CO_2; Smoke density, Conductivity, pH; Temperature of steam and flue gas, steam and condensate flow; Forebay and tailrace level; Flow; Temperature of generator bearings, stators and fields, and of cables; Temperature of engine exhaust.

Jrl Ad N-50-161(1a)

depends on me!
A Slogan For Every American

LEEDS & NORTHRUP COMPANY, 4962 STENTON AVE., PHILA. 44, PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

ELECTRICAL ENGINEERING

Registered United States Patent Office

JULY
1945

The Cover: Welders seal the joints of a turbogenerator frame. In the foreground is a circular frame designed for a 4,500-horsepower electric motor. Westinghouse photo

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NAVY
ALSIMAG

ALCO has been awarded for the fifth time the Army-Navy "E" Award for continued excellence in quantity and quality of essential war production.

STANDARD FOR COMPARISON

It is a fact that other materials offered as insulators for electronic and electrical use *may be judged by the degree to which they approach the combined properties of* ALSIMAG *Steatites.* Study the Property Chart shown below. Whatever you are planning in the electronic or electrical field, the chances are ALSIMAG will do it better. Our specialized knowledge, and our engineering and research facilities are at your service. Let's work together.

AMERICAN LAVA CORPORATION
Chattanooga 5, Tennessee
43RD YEAR OF CERAMIC LEADERSHIP

MECHANICAL AND ELECTRICAL PROPERTIES OF ALSIMAG CERAMICS

ITEM	A.S.T.M. TEST NUMBER	UNIT	STEATITE				
			ALSIMAG A-35	ALSIMAG A-196	ALSIMAG 197	ALSIMAG 211	ALSIMAG 243
Specific Gravity	——	——	2.5	2.6	2.6	2.7	2.8
Density	——	lbs. per cu. in.	.090	.094	.094	.098	.101
Volume	——	cu. in. per lb.	11.11	10.64	10.65	10.26	9.91
Water Absorption	D116-42(A)	%	0—.05	0—.05	0—1	.08	0—.05
Color	——	——	White	White	White	White	Buff
Softening Temperature	C24-35	°C. °F.	1 450 2 642	1 440 2 624	1 445 2 633	1 400 2 552	1 440 2 624
Resistance to Heat (Safe Limit for Constant Temperature)	——	°C. °F.	1 000 1 832	1 000 1 832	1 000 1 832	1 000 1 832	1 000 1 832
Hardness	——	Mohs' Scale	7.5	7.5	7.5	7.5	7.5
Linear Coefficient of Thermal Expansion 25-100°C.	——	Per °C.	6.9×10^{-6}	7.3×10^{-6}	7.7×10^{-6}	7.3×10^{-6}	9.1×10^{-6}
Linear Coefficient of Thermal Expansion 25-600°C.	——	Per °C.	8.7×10^{-6}	8.9×10^{-6}	10.4×10^{-6}	9.2×10^{-6}	10.4×10^{-6}
Tensile Strength	D116-42	lbs. per sq. in.	8 500	10 000	8 500	7 500	——
Compressive Strength	D667-42T	lbs. per sq. in.	75 000	85 000	75 000	65 000	85 000
Flexural Strength	D667-42T	lbs. per sq. in.	18 000	20 000	20 000	18 000	20 000
Resistance to Impact (½" rod)	Charpy D667-42T	inch-lbs.	4.5	5	1.8	2.0	——
Thermal Conductivity (Approximate Values)	——	cal./sec./cm. per °C.	.006	.006	.006	.006	.008
Dielectric Strength (step 60 cycles) Test discs ¼" thick	D667-42T	volts per mil	225	240	210	240	240
Volume Resistivity at Various Temperatures 25°C. 77°F.	——	Ohms per Centimeter Cube	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
100°C. 212°F.			2.1×10^{12}	1×10^{13}	8.1×10^{13}	$> 10^{14}$	5.0×10^{13}
300°C. 572°F.			6.0×10^{7}	1.8×10^{9}	2.5×10^{10}	9.0×10^{13}	7.0×10^{11}
500°C. 932°F.			3.2×10^{5}	9.0×10^{6}	8.8×10^{7}	3.5×10^{10}	1.2×10^{10}
700°C. 1 292°F.			2.3×10^{4}	5.0×10^{5}	4.2×10^{6}	4.8×10^{8}	1.0×10^{8}
900°C. 1 652°F.			7.0×10^{3}	7.0×10^{4}	6.8×10^{5}	2.5×10^{7}	3.0×10^{6}
Te Value	——	°C. °F.	440 824	640 1 184	840 1 544	> 1 000 > 1 832	> 1 000 > 1 832
Dielectric Constant 60 Cycles	D667-42T	——	6.1	5.9	6.3	——	6.3
1 000 K. C.			5.9	5.8	6.0	5.8	6.2
10 M. C.			5.8	5.7	5.8	5.7	6.2
Power Factor 60 Cycles	D667-42T	——	.015	.0022	.0020	——	.0014
1 000 K. C.			.0035	.0021	.0012	.0004	.0004
10 M. C.			.0030	.0015	.0010	.0003	.00035
Loss Factor 60 Cycles	D667-42T	——	.09	.013	.0126	——	.0088
1 000 K. C.			.021	.012	.0072	.0023	.0025
10 M. C.			.017	.008	.0058	.0017	.0022
Capacity Change Per °C.	——	parts per million	+160	+160	+160	+120	+130

ELECTRICAL ENGINEERING
VOLUME 64, NUMBER 7 JULY 1945

AIEE Report on Collective Bargaining

After careful inquiry into present membership practices of unions and prevailing Government attitudes and policy, an AIEE committee has prepared this comprehensive report considering all the implications of the engineer's bargaining position in industry. The report recommends preparation of a factual manual on the American labor movement and establishment of a continuing committee on collective bargaining. Sponsorship of any collective-bargaining agency by the Institute or any of its Sections is disapproved, though the possibility of the AIEE's occasional intervention in disputes as a friend of the court in behalf of its members is recognized.

THE LAST 15 YEARS have witnessed substantial changes in employee–employer relationships. Of the many forces that have accounted for these changes, the most important are

1. The great depression which developed a strong urge for security on the part of wage earners.
2. Social legislation designed to bring about a better distribution of national income and to provide greater security for workers through the establishment of minimum labor standards, various types of social insurances, as well as by the encouragement of labor organizations and collective bargaining.
3. The growth in the membership and power of organized labor, especially in the mass-production industries.
4. The split in the American labor movement.
5. The shortage of man power occasioned by World War II and the controls introduced by unions and the Federal Government affecting this shortage.

Until very recent years the great majority of employees have dealt as individuals with their employers in establishing wages, hours, and conditions of employment. In 1929—one of our most prosperous peacetime years—the membership of organized labor totaled approximately 3,500,000 workers. As the depression set in, union membership slowly but steadily declined to under 3,000,000. In 1933 the labor movement surged forward aided by improved business conditions but more especially by the National Industrial Recovery Act and later by the National Labor Relations Act and the policies carried out by the National Labor Relations Board and by the National War Labor Board. Today labor organizations, according to various estimates, have a membership of between 12,000,000 and 13,000,000, and the wage contracts negotiated by them probably apply to an additional 3,000,000 or 4,000,000.

The character of the American labor movement has undergone considerable change during these years. This change has been accentuated by the existence of two competing national federations (the American Federation of Labor and the Congress of Industrial Organizations), the United Mine Workers of America, and the Confederated Unions of America. The last-mentioned organization is an association of independent unions. To retain or to win leadership in the field each of these organizations has found it necessary to expand its jurisdiction and increase its membership. The movement, which had been largely one of production workers, rapidly spread to clerical employees. Later the drive was broadened to include professional employees.

It was the pressure to bring engineers into heterogeneous unions comprising professional and nonprofessional employees which are affiliated with the AFL or the CIO that led to the appointment of the AIEE committee on collective bargaining and related matters.

STATEMENT OF THE PROBLEM

To clarify its own thinking the committee has defined the problem which the Institute has placed before it as follows:

> Should the American Institute of Electrical Engineers take any action with respect to the determined efforts of unions of professional and nonprofessional workers to organize and sometimes to compel professional employees, including electrical engineers, to join their associations for collective bargaining, mutual aid, and other purposes? If so, what action should be taken?

The National Labor Relations Act guarantees employees the right to organize and bargain collectively and forbids employers to interfere with self-organization or to refuse to bargain with certified groups of employees. There always will be some employers who, unless restrained, will disregard the rights and legitimate wants of their workers, and severe competition within industry may occasion reductions in labor standards which progressive and socially minded employers deplore. Also drastic curtailments in business activity give rise to unemployment, loss of earnings, and sometimes unfair terms and conditions of work. It is for these and other reasons that employees have been guaranteed protection in the exercise of their rights to form unions and to negotiate wage contracts. The voluntary exercise of these rights cannot be denied in a free society. However, the National Labor Relations Act does not compel anyone to join a union. On the other hand, the Act does not prevent employers and employees from entering into closed-shop or union-shop agreements which, as a condition of employment, require membership in a particular union.

Many engineers believe that the inclusion of professional employees in an organization of both professional and non-

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A report prepared by the AIEE committee on collective bargaining and related matters: I. Melville Stein, *chairman;* E. P. Yerkes, *secretary;* O. W. Eshbach; W. R. Hough; A. C. Streamer; and B. Van Ness, Jr.

The AIEE committee on collective bargaining and related matters was very fortunate in obtaining the consulting services of Waldo E. Fisher, professor of industrial relations at the Wharton School, University of Pennsylvania. A student of industrial relations for over a quarter of a century and author of many books, reports, and papers relating to that subject, Doctor Fisher has served Government, society, and industry in many important assignments of which the following few are representative: consultant to National War Labor Board, member of staff of International Labor Office, past president Philadelphia Industrial Relations Association.

On Doctor Fisher's recommendation and through his co-operation, the committee has conferred with William M. Leiserson. In introducing a recent article by Doctor Leiserson in *The American Magazine*, the editor made the following statement: "Doctor Leiserson has perhaps the most impartial and comprehensive view of labor problems of any man in America. In the last 35 years he has served as a mediator and arbitrator of labor disputes in many industries. He has made studies of labor problems for cities, states, and the National Government. In addition to being chairman of the National Mediation Board, he has served as chairman of the National Petroleum Labor Policy Board, member of the National Labor Relations Board, and chairman of the National Railway Labor Panel. He is now visiting professor of economics at Johns Hopkins University."

professional employees in which the nonprofessional workers constitute the majority would not give engineers adequate protection, inasmuch as their wages and conditions would be negotiated by leaders elected and maintained in power by nonprofessional workers whose interests would have to come first and whose demands might be satisfied at the expense of the professional employees. The interests of nonprofessional employees and of professional employees in many respects are not similar. Because of their education and training, and their genuine concern with the effective utilization of labor, materials, machines, and natural forces, as well as their obligations under their codes of professional conduct, the engineers may prefer to unite to formulate their own objectives, policies, and methods and to negotiate their wages and terms of employment.

The committee is of the opinion that the Institute should make it a matter of record that it is not opposed to labor organizations nor to collective bargaining, so long as the goals of labor organizations do not run contrary to the law or conflict with the best interests of the engineering profession. It believes that the professional engineering societies should have but one concern with labor organizations or unions, namely, to see that professional employees are not compelled to join labor organizations, especially when such organizations are dominated or controlled by nonprofessional employees, and are not forced into bargaining units dominated or controlled by nonprofessional employees.

The law does not require anyone to join a labor organization. Direct compulsion may occur in only one way, namely, when a union-shop or closed-shop contract is put into effect. (For definition of various types of union-security arrangements see Appendix I.) The foregoing types of union–employer relationships in the great majority of cases are established through collective bargaining. In only one case has a Federal agency been willing to urge the closed or union shop on an employer, and that was in June 1941, when the National Defense Mediation Board recommended, with but one dissenting vote, that the Bethlehem Steel Corporation accept a master agreement providing for a closed shop which had been submitted to the company by the union representatives of the shipbuilding employees on the Pacific Coast. Several months later, the same Board refused to order the steel companies to grant the union shop to the United Mine Workers of America for its members employed in coal mines operated by these companies. The latter decision brought about the Board's demise.

The National Labor Relations Board has no authority under the National Labor Relations Act to order the introduction of a closed or union shop. The National War Labor Board, presumably in return for the no-strike pledge, has ordered maintenance-of-membership clauses to be em-

Collective Bargaining and the Professional Employee

In January 1944 the board of directors of the AIEE authorized the appointment of a committee to study and report on collective bargaining and related matters. At about the same time some discussions were started leading to the establishment in July 1944 of a joint committee of three of the professional engineering societies. This committee's function is also that of a study or survey group, and it became the Joint Committee on the Economic Status of the Engineer. The three societies participating in the joint activity are the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the AIEE. The American Institute of Mining and Metallurgical Engineers and the American Institute of Chemical Engineers have been invited to participate in the work of the joint committee, and, pending formal action on the part of these two societies, their representatives have been participating informally.

The scope of the survey work being undertaken by the joint committee is considerably broader than the subject of collective bargaining, but one of the survey groups set up by the joint committee is a committee on collective bargaining by engineers in professional work.

The recommendations of the report of the AIEE committee on collective bargaining and related matters were approved tentatively by the AIEE board of directors at its meeting on May 29, 1945, pending further consideration by the membership as a whole, and the report, including its recommendations on policy, now is being studied by the Joint Committee on the Economic Status of the Engineer.

To facilitate the co-operative work of the Joint Committee on the Economic Status of the Engineer, that committee has recommended that the tentative report of the AIEE committee on collective bargaining and related matters be published promptly not only in *Electrical Engineering*, but also in the monthly publications of the other professional engineering societies. This is intended to give the joint committee the benefit of the comments and criticism of all engineers doing professional work rather than only those of readers of *Electrical Engineering*.

Your criticism and comments are earnestly solicited. These should be sent promptly to:

Mr. E. P. Yerkes
Bell Telephone Company of Pennsylvania
1835 Arch Street
Philadelphia 3, Pa.

In writing please indicate the professional engineering society or societies to which you belong.

bodied in wage contracts and has ordered the renewal of a closed- or union-shop clause during the negotiation of a new contract. It has not, however, ordered the adoption of either a closed or a union shop where these types were not in effect in the expiring contract.

Under closed-shop or union-shop contracts covering all employees in the bargaining unit, professional employees with no supervisory responsibilities could be compelled to join a labor organization which might be dominated by nonprofessional employees. Such compulsion could happen under maintenance-of-membership contracts, only if professional employees were members of the labor organization and failed to exercise their option to resign during the 15-day period set aside for this purpose.

Indirect compulsion, however, may occur in other ways. Professional employees may be forced into unions of nonprofessional workers by pressure applied by union members. Redress from physical force and threats does not fall within the jurisdiction of the National Labor Relations Board but is a matter that must be taken up with the courts. Also, indirect compulsion takes place when the National Labor Relations Board makes a decision which, because of the absence of a qualified group of professional employees, brings professional employees into a bargaining unit composed primarily of nonprofessional employees. In this case there is direct compulsion with reference to placing professional employees in a *bargaining unit* composed primarily of nonprofessional employees, but there is no direct compulsion to join the *organization* of nonprofessional employees which is recognized as the *bargaining agent*. However, to avoid ill feeling between the professional employees and their bargaining agent and to take advantage of the only opportunity to be represented in the negotiations covering the terms of their employment, the professional employees might find it necessary to join the organization controlled by nonprofessional employees.

To protect themselves against either direct or indirect compulsion, engineers may find that their best defense is an organization either of engineering employees, or of engineering and other professional employees, associated with or independent of a national federation of labor.

It is the committee's considered opinion that engineers, guided by their personal convictions and the circumstances in which they find themselves, should decide for themselves whether they wish:

1. To join a union associated with one of the national federations of labor which may be either a union of professional employees only or a union of both professional and nonprofessional employees.

2. To join with other professional employees for the purpose of forming an independent organization composed exclusively of engineers or of engineers and other professional employees.

3. To refrain from joining any labor organization.

Except in cases involving closed-shop or union-shop contracts, the engineer's right to make his own choice is guaranteed by the National Labor Relations Act.

The committee believes that electrical engineers should be fully informed as to their rights and opportunities under the National Labor Relations Act but that their choice of a bargaining agency should not be influenced by the Institute, beyond its indicating to them that, in the interest of their professional status, it would be undesirable for them to belong to, or to be represented by, a labor organization dominated or controlled by nonprofessional employees.

POSSIBLE COURSES OF ACTION TO BE TAKEN BY THE INSTITUTE

Five courses of action suggest themselves to the committee. The Institute may:

1. Do nothing.

2. Study the situation and prepare a manual for the individual members, setting forth what the Institute and similar organizations may and may not do and indicating clearly what courses of action are open to individuals or groups.

3. Set up machinery within the engineering societies which will enable them to intervene as a friend of the court for the purpose of assisting engineers engaged in engineering work of a professional nature to remain outside of bargaining groups of nonprofessional men, or to exercise their right to bargain collectively through representatives of their own choosing.

4. Attempt to set up professional organizations through the Institute or its Sections, as collective-bargaining agencies for professional men.

5. Attempt to secure a modification of the Wagner Act which would either:

(*a*). Exempt engineers from the provisions of the Act

or

(*b*). Put professional employees in a separate category under the Act.

The committee believes that the AIEE would fall short of fulfilling its obligations to its members if it were to do nothing at all. While the Institute is interested primarily in increasing scientific and technical knowledge in the field of engineering, it cannot ignore the impact of political and social changes in our national economy upon the engineering profession. The recent developments in the field of industrial relations fall into this category.

The committee also believes that some action is necessary to ensure the maintenance of a high professional standing among engineers in conformance with the objectives stated in the AIEE constitution:

Its objects shall be the advancement of the theory and practice of electrical engineering and of the allied arts and sciences and the maintenance of a high professional standing among its members.

On the other hand, the course of action listed as 5(*a*) has little to offer as a solution of the problem facing engineers. Those close to the situation in Washington hold that efforts to exempt engineers from the provisions of the National Labor Relations Act have very little chance of success. The Act applies to all employees including doctors, lawyers, and other professional employees, working in establishments engaged in or affecting interstate commerce. It would be difficult to justify exemption for engineers as a group, especially since many engineers undoubtedly would protest such action. It also has been pointed out that, even if this objective could be achieved, the problem would still remain. Unions could and probably would accept engineers as members and nothing in the National Labor Relations Act would preclude such action, even if engineers were excluded from the provisions of the Act. Moreover, in those instances in which engineers believe they need a labor organization to protect their interests and the employer refuses recognition, the bargaining agency for the engineers would have to resort to strikes to obtain a wage contract, since the exclusion of engineers from the National Labor Relations Act would not permit certification by means of an election under the supervision of the National Labor Relations Board. The engineers would be in exactly the same position in which the foremen found themselves prior to a recent decision.* When the National Labor Relations Board held that it would not establish a bargaining unit for foremen and would not certify bargaining representatives for them, a wave of foremen's strikes spread throughout industry. As a result foremen through their organization, the Foremen's Association of America, have secured recognition and union agreement in certain establishments. To clarify the situation, the National Labor Relations Board found it necessary to hold a hearing in Detroit in December 1944 for the purpose of reconsidering its position on the foremen question and of deciding whether they were entitled to all the rights that other employees enjoy under the National Labor Relations Act. Lastly, the fact that engineers now have the right to join unions whenever such a course of action seems desirable gives them, as individuals, a potential bargaining power with their employers which many engineers would not want to surrender.

Through course 5(*b*), instead of attempting to have engineers in professional work excluded from the provisions of the National Labor Relations Act, the attempt

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*** On March 26, 1945, in a case involving the Packard Motor Car Company and the Foremen's Association of America, the Board reversed by a two to one vote its Maryland Drydock decision and granted organizations of foremen, which are unaffiliated and independent of other unions, the right to petition the Board and, where they can win an election, to be certified as the legal agen of supervisory employees in a specified bargaining unit.**

might be made to modify the Act so as to place professional employees, including engineers, in a separate category under the Act. Presumably, under such modification professional employees would be considered ineligible for inclusion in bargaining units of nonprofessional employees but would still have the right under the Act to be placed in bargaining units of professional employees, if they so desired and to be represented by representatives of their own choosing. In principle, at least, such an arrangement would seem to be better than any proposed to date with reference to modification of the existing law affecting collective bargaining by professional employees. It would avoid having professional employees represented by nonprofessional employees or by representatives chosen by a group in which nonprofessional employees predominated and yet it would not deny professional employees any rights guaranteed to other types of employees.

If requested to do so by a substantial majority of their professional employee members, the engineering societies could quite properly advocate and work for such a modification of the National Labor Relations Act. In doing so they would be following a course similar, in principle, to that sponsored by the American Federation of Labor, which has advocated an amendment to the Act providing for craft bargaining units when requested by employees in particular crafts. Naturally the outcome of such a procedure cannot be predicted, but it seems unlikely that the necessary modification of the Act could be accomplished at an early date, if at all. Meanwhile, professional employees would have no assurance that they would not be represented by representatives chosen by groups dominated or controlled by nonprofessional employees. In this connection it should be pointed out that, if professional employees, through the formation of, or affiliation with, organizations of professional employees, were assigned by the National Labor Relations Board to bargaining units composed solely or predominantly of professional employees, they would be in a no less favorable position in the event that the above modification of the National Labor Relations Act were accomplished later.

An arrangement similar to that indicated in course of action 5(*b*), but providing for a separate order-in-council and board, recently was advocated in Canada as a substitute for the present Canadian Wartime Labour Relations Act (P.C. 1003) in so far as that Act involves professional employees. The attempt was not successful but did result in a temporary modification of the procedures under the Act which apparently would assure the right of professional employees to be included in bargaining units of professional employees, even though they had been included previously in heterogeneous bargaining units or units of nonprofessional employees.

Course of action 4 would seem to be undesirable for a number of reasons. The right to bargain collectively is not an abstract right but one to be exercised in terms of specific bargaining units. To enjoy this right employees must form or join organizations which are free from employer domination and control. Section 8 of the Wagner Act specifically states that it shall be an unfair labor practice for an employer:

1. "To interfere with, restrain, or coerce employees in the exercise of the rights guaranteed in Section 7" which reads "employees shall have the right to self-organization, to form, join or assist labor organizations, to bargain collectively through representatives of their own choosing, and to engage in concerted activities, for the purpose of collective bargaining or other mutual aid or protection."

2. "To dominate or interfere with the formation or administration of any labor organization or contribute financial or other support to it . . . ."

The committee believes that any bargaining agency for engineers or professional employees set up by the American Institute of Electrical Engineers or its Sections later might find itself handicapped at subsequent hearings before the National Labor Relations Board. Competing unions undoubtedly would challenge its status as a bona fide bargaining agency, inasmuch as it had come into existence with the help of an association whose membership and more especially its officers and directors include employing engineers and management representatives. Professional labor leaders undoubtedly would try to prove that these agencies were initiated, sponsored, assisted, and indirectly controlled by an association dominated by employers and their representatives and would demand that they be disestablished. Thus these Institute-sponsored bargaining agencies always would be in the position of having to prove to the National Labor Relations Board that they were not employer dominated.

The committee believes it would be a disservice to the individual members as well as the Institute to endorse a procedure which later might be declared to be in violation of the National Labor Relations Act or would hamper engineers in subsequent efforts to exercise their rights under that Act. The committee would like to add that, just as it considers it unwise for nonprofessional workers to dominate a minority of professional employees, so it believes it equally unwise for the Institute to take any action which might leave the impression that its members who are employers or who occupy official positions with management have any desire to impose their ideas as to organization or collective bargaining on those members of the Institute who happen to be employees.

For this reason and because the committee believes that the creation of labor organizations for collective bargaining is a function which falls outside the field of activity of the Institute, it concludes that the Institute itself or any of its Sections should refrain from sponsoring either directly or indirectly the formation of bargaining agencies for its employee members and from assisting in the formation of such organizations.

The committee believes that course of action 3 should not be followed except under unusual circumstances. It is true that professional organizations have intervened for their members as a friend of the court. It is quite possible that the National Labor Relations Board may continue to listen to their contentions in specific situations. The committee has been advised on good authority that intervention probably would not be granted to professional engineering societies, if the purpose were to help their members to keep out of a particular union or to tell the Board how engineers should be organized. The Board takes the position that a group of employees may organize in any way it sees fit as long as it keeps free from employer domination. It also maintains that elections are held not to determine whether employees want to stay out of a union but to ascertain the wishes of employees concerning a union or several unions seeking certification. Intervention may be justified in certain instances especially where the engineering members of a bona fide organization of professional employees request the Institute to intervene in their behalf. Under such circumstances the Institute would have an interest in the case, because it would be assisting certain employees involved in the case to obtain what to them is a satisfactory bargaining unit. It then could take the position that engineers or professional employees, because of their training, responsibility, nature of work, and so forth, are a homogeneous group for purposes of collective bargaining.

The committee has been informed that engineering associations, unless they can establish an interest in the case, probably would be allowed to intervene as a friend of the court only in very rare instances, such as an occasion when the Board is hearing oral arguments in Washington on the record of a particular case, previously heard in the field by a trial examiner, in which the question before the Board is a difficult one involving considerations of wide public interest. A case in point was the hearing for the purpose of oral argument held in connection with foremen's unions at which a number of outside organizations were permitted to intervene and file briefs. Thereafter, the foremen's cases were handled like the ordinary run of representation cases.

It should be pointed out that intervention will have little value unless it is undertaken early in the process—certainly before the situation becomes crystallized.

In order to eliminate duplication of effort and conflicting testimony, it may be advisable for the various engineering as-

Recommendations

The committee on collective bargaining and related matters recommends that the American Institute of Electrical Engineers adopt the following tentative policy:

1. Prepare a manual for members presenting the essential facts about the American Labor movement and the National Labor Relations Act (Wagner Act) and setting forth (1) what the Institute may and may not do and (2) the courses of action that are open to its members.

2. Seek the establishment of a joint committee composed of representatives of the various engineering societies which would serve as a clearing center for these associations and, in those cases in which two or more societies desire and have the right to intervene as a friend of the court on behalf of their members, make arrangements for a common counsel.

Note. The committee has been informed that the Institute generally will have little opportunity to intervene as a friend of the court in labor cases involving engineers. It believes, however, that such action may be both possible and desirable in certain circumstances. A joint committee would enable each society to join with other engineering societies, to act alone, or to refrain from any action depending upon the issues and circumstances in a given case.

3. Establish a continuing committee on collective bargaining and related matters in order that the Institute may be kept informed about new developments concerning unionization and collective bargaining.

4. Refrain from establishing collective-bargaining agencies for engineers which are directly or indirectly associated with the Institute or its Sections, and from assisting in any way in the actual formation or administration of a labor organization for engineers.

sociations to establish a joint committee which would serve as a clearing house for these associations and to arrange for a common counsel for participating associations in those cases in which intervention is sought. Under such an arrangement each engineering association could elect to intervene in any particular case with the minimum of expense and wasted effort. It would have the additional advantage of reducing to a minimum the confusion and irritation, as far as the National Labor Relations Board is concerned, that undoubtedly would result from independent action on the part of each association. This procedure would enable the Institute: (*a*) to join with other engineering associations, (*b*) to act alone, or (*c*) to refrain from any action, depending upon the issues and circumstances in a given case.

With reference to course of action 2, the committee believes that the preparation of a monograph entitled "Collective Bargaining and the Professional Employee" should be prepared for the information and guidance of members of the AIEE. The exact nature and specific content of this monograph should be given careful study and be prepared under the direction of a committee of the Institute. It might well include:

1. Statement of the problem facing the professional employee.
2. The American labor movement.
   (*a*). Why it came into being.
   (*b*). Its aims and goals.
   (*c*). Its structure: various types of local and national unions; the AFL; the CIO; other important national organizations.
   (*d*). Its functions, policies, and tactics.
   (*e*). The extent of organization.
3. The National Labor Relations Act (Wagner Act).
   (*a*). The rights and responsibilities of professional employees under the Act.
4. Collective bargaining.
   (*a*). Function.
   (*b*). Subject matter.
   (*c*). Techniques.
5. Courses of action open to engineers and other professional employees to protect their own interests.

DETERMINING THE BARGAINING UNIT

The National Labor Relations Act guarantees employees the right to self-organization, that is, to form or join organizations and to bargain collectively through representatives of their own choosing. The Board has taken the position that any employee organization has complete freedom to define its membership qualifications as it sees fit, as long as it keeps free of employer domination. In other words, the composition of a labor organization, even though it includes professional workers, foremen, and employers in its membership, is of no concern to the Board, unless the organization is employer minded or employer dominated. Employer-initiated and employer-dominated unions are illegal under the Act and, therefore, have no standing before the Board.

The Board's primary concern in representation disputes is with the character of the bargaining unit. It is important to note that the bargaining unit and the membership of a union need not be coextensive and frequently are not. An employee organization need not bargain for its entire membership nor even for any of its members. It may bargain for employees entirely outside of its membership. As a matter of fact, collective bargaining for a particular group of employees may be done by an outside individual, a small committee, a union, or some other association. All that the Act requires is that the representative or representatives be of the employees own choosing and be free of employer domination.

Many of the disputes before the Board arise over the bargaining unit claimed by the representatives of the union seeking recognition.* In all representation cases the Board is required by law to decide specifically the question as to what bargaining unit is appropriate.** Where there is only one organization involved and the organization has been designated by approximately 30 per cent of the employees in the bargaining unit, the Board will hold an election and, unless the employing company presents valid objections, certify the organization, should it win the support of the majority of the qualified employees voting. It is where two competing labor organizations claim identical or overlapping jurisdiction that the Board must decide which one shall be the bargaining agent. In doing so the Board's chief aim is to bring together in a single unit those employees who have a community of interest which is likely to further harmonious organization and facilitate the aims of collective bargaining. Conflicting claims, as well as justifications which go back over a period of years, sometimes make the determination of a bargaining unit a difficult task. The Board has found it necessary, therefore, to set up a number of criteria to be used as a guide in the making of a decision. These criteria may be summarized as follows:[1]

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* The Board also handles complaint cases involving charges of employer violation of the provisions of the Act relating to unfair labor practices. These disputes, however, have no bearing on the issues under discussion.

** See Appendix I for distinction between "bargaining unit" and "bargaining agent."

1. The history, extent, and type of organization of employees.
2. The history of collective bargaining.
3. The history, extent, and type of organization of employees in other plants of the same employer, or other employers in the same industry.
4. The skill, wages, work, and working conditions of the employees.
5. The desires of the employees.
6. The eligibility of the employees for membership in the union or unions involved.
7. The relationship between the unit or units proposed and the employer's organization, management, and operation.
8. Whether an association of separate employers is in existence exercising employer functions, and having a history of collective bargaining on a multiple-employer basis.

No precise weight is given to any of the above criteria. Generally several considerations are involved in each case. The Board holds that the complexity of the problem precludes the use of rigid rules in the determination of the unit appropriate for the purposes of collective bargaining.

Considerable weight, however, is given to the desires of employees in representation cases in which rival organizations have advanced conflicting jurisdictional claims. In such situations the Board applies the Globe doctrine—so named because the principle was first enunciated in the case of the Globe Machine and Stamping Company and the Metal Polishers Union, Local Number 3, and others. Under this doctrine the employees are permitted to decide by vote whether they want a separate craft union or desire to be included with other employees in a larger bargaining unit. If the majority of a given craft or related crafts vote for a craft union, the Board rules that the craft shall be the bargaining unit. If the majority vote for the larger bargaining unit, the Board denies separate craft representation. Incidentally, the American Federation of Labor now is advocating an amendment to the Wagner Act which would make this procedure a part of the Act.

DEFINITION OF PROFESSIONAL EMPLOYEE

Because organizations of professional employees seeking certification may find themselves facing competing unions also claiming jurisdiction of salaried employees, a definition of "professional employee" is necessary.[*] The distinction between "professional status" and "nonprofessional work" was a subject of controversy in the matter of Shell Development Company, Inc., and the International Federation of Architects, Engineers, Chemists, and Technicians, case XX-*R*-552. It well may be an issue in future cases before the Board.

The committee suggests the following definition: A person employed in a bona fide professional capacity is any employee engaged in:

1. Work predominantly intellectual and varied in character, as opposed to routine mental, mechanical or physical work.
2. Work requiring the consistent exercise of discretion and judgment in its performance.
3. Work of such a character that the output produced or the result accomplished cannot be standardized in relation to a given period of time.
4. Work requiring knowledge of an advanced type in a field of science or learning customarily acquired by a prolonged course of specialized intellectual instruction and study, as distinguished from a general academic education and from an apprenticeship, and from training in the performance of routine mental, manual, or physical processes.
5. Work predominantly original and creative in character in a recognized field of technological endeavor involving invention, imagination, or talent.
6. Work of a nonprofessional character when scheduled for students or graduates of accredited colleges or universities as a part of their training and education to acquire a professional status as defined herein.
7. Work of a nonprofessional character performed temporarily as a part of a professional investigation.

It should be stated that criteria 1, 2, 3, and 4 have been taken without change from the definition of professional employee as defined by the Wage and Hour Division.[2] Criterion 5 also is taken from this report but in a slightly modified and abbreviated form, while 6 and 7 have been added to meet the requirements of junior engineers who are in the process of attaining a professional status, or engineers who have been assigned temporarily to nonprofessional work in order to further their research or investigation.

STATUS OF YOUNG ENGINEERS DOING NONPROFESSIONAL WORK

The Committee has given serious consideration to the status under the National Labor Relations Act of young engineers who may be attending or who have graduated from an accredited engineering school but who, as a part of their training, are working on nonprofessional jobs. The question is frequently asked—Would young engineers on nonprofessional jobs be compelled to join organizations of nonprofessional employees while performing such work, or would they be permitted to join an organization of professional employees if they desired to do so?

In answering this question it should be pointed out that engineers could be compelled to join a labor organization only if a closed or union shop prevails in the bargaining unit in which the engineers are performing nonprofessional work. The Board does not order employees to become members of labor organizations. Its task is to decide what the bargaining unit shall be in specific situations which are brought before it. In determining the bargaining unit, the Board must decide whether engineers shall or shall not be included.

The action to be taken by the Board probably would vary with the circumstances in each case. If a union and an employer both agreed that young engineers on nonprofessional work should be included in a particular bargaining unit then the Board as a rule would accept the arrangement. Again, if a union at the request of the employer agreed to exclude such employees, the Board in the absence of any protests probably would accept this disposition of the matter. If a union insisted upon the inclusion of such engineers in a bargaining unit, the Board presumably would apply the criteria listed above and make a decision on the basis of the factors prevailing in a given situation. If young engineers in this category had been members of a bona fide union in the plant or industry for a period of years, the Board undoubtedly would be reluctant to disturb the prevailing arrangement. Where no precedent had been established and a majority of the engineers had refused to sign membership cards but instead insisted upon membership in an association of professional employees, the Board in all likelihood would give careful consideration to their request. In such a situation resort to the Globe doctrine would seem to be the logical course of action.

We may conclude, then, that engineers can be compelled to join a labor organization only where they have been assigned to a particular bargaining unit and a closed or union shop has been established for that unit by voluntary agreement between the union and the employer.

TYPES OF LABOR ORGANIZATIONS OPEN TO ENGINEERS

One of the problems which would have to be faced by engineers is the selection of the type of labor organization which they would wish to represent them when some form of organized representation becomes desirable. A number of possibilities present themselves. Each of the types of organizations listed below may or may not be associated with a national labor organization or a national federation of labor unions. The various possibilities are:

1. An organization of production workers
2. A heterogeneous organization of professional and nonprofessional employees.
3. An organization of engineers.
4. An association of engineers and employees in closely related professions such a chemists, physicists, and so forth.
5. An organization of all professional employees.

In the opinion of the committee th first of these possibilities is definitely un suited to the needs of the engineers. Acceptance of the second would depend upon the history and status of industrial relations in the company, the wishes of the employees, the attitude and integrity of management, and the economic position of the company in the industry. The remaining three possibilities are all suitable forms of labor organizations for engineers. The inclusion of all employees engaged in professional work in a single bargaining agency would make for a larger membership, which in turn would give the agency more prestige whether it becomes associated with one of the national federations of labor organizations or operates as an independent organization. Such an association, when organized on a national basis, would have a substantial treasury which would enable it to engage organizers, retain a research staff, and maintain competent officers and counsel. On the other hand, the more restricted the bargaining agency the greater the community of interest among the members and the easier the task of administration. Internal conflicts of interest would be less likely to arise and objectives and programs could be developed more easily, but external conflicts, such as jurisdictional disputes, would be more likely to occur. Moreover, restricted organizations add to the difficulties of maintaining mutually satisfactory industrial relations, and many separate bargaining agencies not only are time consuming but also complicate the collective-bargaining process.

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[*] A definition of a professional employee helps to define the jurisdiction of a professional-employees organization and should be an important guide to the NLRB in determining an appropriate bargaining unit.

The committee believes that the choice of the form of organization should be left to the engineers and their associates engaged in professional work. It recognizes that the appropriate bargaining agency may well differ from establishment to establishment. It wishes to point out, however, that the Institute may quite properly advocate and urge on its employee members that in all cases before the National Labor Relations Board they ask for any one of the last three forms of organizations, namely, an association for engineers alone, an association for engineers and their associates in closely related professions, or an association of all employees engaged in professional work. A statement addressed to its members pointing out the form of organization which it believes to be in the best interests of the engineer is quite in order and would not be detrimental to the Institute or its members. The foregoing, however, would not be a proper argument for the Institute to make directly to the National Labor Relations Board in an individual dispute case, because in such cases the Board is concerned only with the wishes of the employees and the enforcement of the Act.

Where a bargaining agency for professional employees exists or is being formed, the committee believes that every effort should be made to include junior engineers. If young engineers are left out of the professional unit and included in a nonprofessional unit in which they happen to be working temporarily, their interests will not be fully protected. It should be noted that this arrangement has precedent. For example, a pattern maker who is temporarily assigned to work with production employees usually is excluded from the bargaining unit of production workers and retained in the unit of the pattern workers, most of whom ordinarily work in a separate pattern shop.

If young engineers are included in a bargaining unit of production workers in which they happen to be working temporarily, they may be brought under a closed-shop or a union-shop arrangement which might give rise to misunderstandings and irritation when they desired to move up to their regular professional positions. Moreover, they may want to belong to a professional organization during the time they are temporarily assigned to nonprofessional work, and, if covered by a closed-shop agreement, they would have to pay dues in two labor organizations. To avoid such complications it would seem advisable to recommend to these young engineers that, whenever they deem it advisable to choose a collective-bargaining representative, they seek admission to a group representing professional employees.

Appendix I. Glossary

Employer as defined in the National Labor Relations Act "includes any person acting in the interest of an employer, directly or indirectly, but shall not include the United States, or any state or political subdivision thereof, or any person subject to the Railway Labor Act, as amended from time to time, or any labor organization (other than when acting as an employer), or anyone acting in the capacity of officer or agent of such labor organization." (Section 2(2).)

Employee as defined in the Act includes "any employee, and shall not be limited to the employees of a particular employer, unless the act explicitly states otherwise, and shall include any individual whose work has ceased as a consequence of, or in connection with, any current labor disputes or because of any unfair labor practice, and who has not obtained any other regular and substantially equivalent employment, but shall not include any individual employed as an agricultural laborer, or in domestic service of any family or person at his home, or any individual employed by his parent or spouse." (Section 2(3).)

Representative as defined in the Act may be "any individual or labor organization." (Section 2(4).)

Labor Organization as defined in the Act "means any organization of any kind, or any agency or employee representation committee or plan, in which employees participate and which exists for the purpose, in whole or in part, of dealing with employers concerning grievances, labor disputes, wages, rates of pay, hours of employment, or conditions of work." The Board, in accordance with the purpose of the Act (specifically Section 8(2)) has refused to certify unions initiated, aided or dominated by employers.

Bargaining Unit comprises those classifications of employees that are (*a*) to be included for the purposes of collective bargaining and (*b*) to be covered by the wage contract. The definition may specify the classification to be included or it may list those to be excluded. It may be a craft, plant, company or a subdivision thereof. (Section 9(*b*).) It is important to note that the Board makes a distinction between the bargaining unit and the labor organization of employees. The Board is not concerned with the composition of the organization so long as it is free from employer domination. Its membership may be less inclusive, more inclusive or coextensive with the bargaining unit. A labor organization of professional employees, for example, could admit to membership young engineers, professional employees temporarily engaged in nonprofessional work, and employees whose work is of a semiprofessional nature. It might not, however, be certified by the Board as the bargaining agency for any of these special classifications. In making its decision as to what the bargaining unit shall be, the Board strives to bring together in one single unit those employees who have a community of interest which is likely to further harmonious organization and facilitate the objectives of collective bargaining.

Majority-Rule Principle means that where a union is designated by the majority of the voting employees in a bargaining unit, it automatically becomes the sole bargaining agent for all employees (nonmembers as well as members) in the unit.

Union Status is the basic relationship which prevails between the union and the employer under a wage contract. It is a matter of great importance to both the union and management. The more common types of union–management relationships are:

Closed Shop. An arrangement under which (*a*) all employees in the *bargaining unit* are required to belong to the union as a condition of employment and (*b*) the employer agrees to hire only union members (sometimes also to hire only through the union) so long as the union is able to supply needed employees.

Union Shop. An arrangement under which the employer may hire new employees from any source but said employees must become members of the union, usually after a specified trial period.

Preferential Shop. An arrangement under which union members are given special consideration in certain aspects of employment, most commonly in lay-offs and rehiring and sometimes in hiring and promotion.

Maintenance of Membership. An arrangement which does not require any employee to join the union, but which requires those employees who were members when the contract was signed and who failed to resign during the "escape period" (usually 15 days) as well as those who later joined the union, to continue as members during the life of the agreement.

Sole Bargaining Agent. An arrangement under which the union is recognized as the only bargaining agency for all the employees in the unit. Under this type of union–management relations employees may either join or refrain from joining the bargaining agency.

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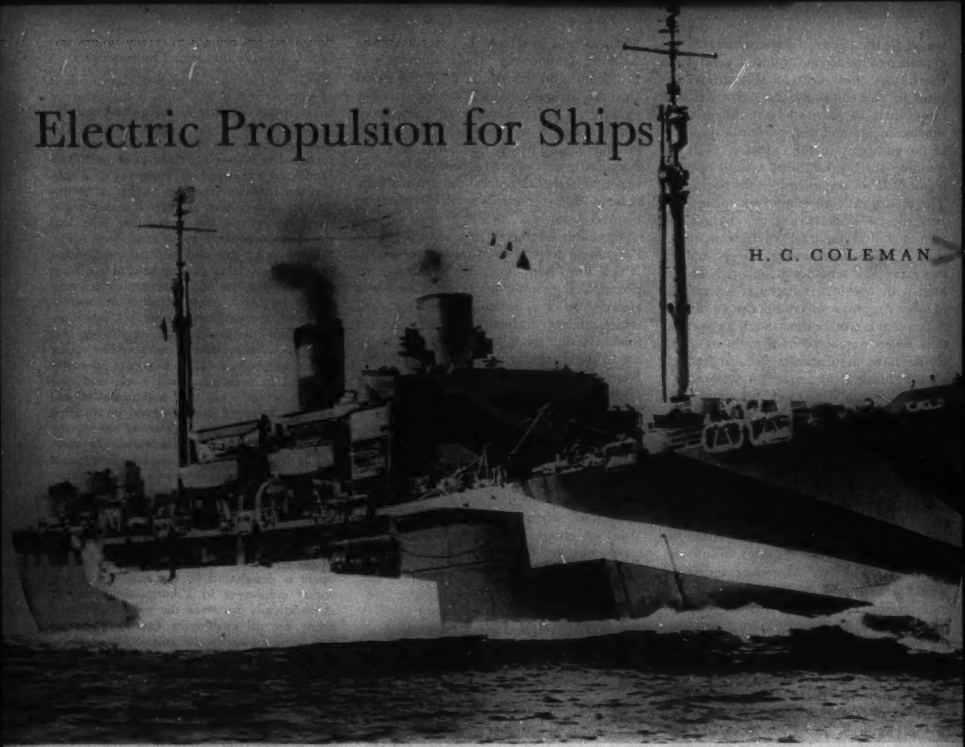
Electric Propulsion for Ships

H. C. COLEMAN



This article contains a brief outline of the fundamental component parts and scheme of operation of the various types of electric propulsion systems. Historical data on the electric drive are included which indicate present trends and possible future developments.

ALTHOUGH the application of electric equipment for the propulsion of ships had a humble beginning and progress was slow at first, its use has been extended greatly, particularly in the last 20 years, so that now electric propulsion, both by direct and alternating current, is a very important factor in marine transportation. This is evidenced by the fact that up to October 1, 1944, more than 870 propulsion plants of the turbine-electric type totaling approximately 7,600,000 shaft horsepower and more than 940 of the Diesel-electric type totaling more than 2,600,000 shaft horsepower had been built or contracted for in the United States.

Many applications of the turbine-electric type with a-c drive are being made on passenger and cargo liners, tankers, and Coast Guard cutters. The present war has brought about the use of turbine-electric a-c drive on many Maritime-Commission and Navy ships, partly because of a lack of gear-cutting capacity. It would seem that this type of electric propulsion will find its future field of application mainly on vessels of special requirements where, for instance, the auxiliary power load in port is an appreciable percentage of the total power of the propulsion plant, so that the main generator may be used for this supply; also possibly, it will be used wherever operating conditions dictate the need for full power astern when maneuvering.

Developments on the Diesel engine prior to and during the war have led to higher-speed and lighter-weight machines which can be applied most conveniently to ship propulsion in multiple units by utilizing electric transmission. This type of prime mover with d-c equipment will probably continue to be a favorite form of drive for special classes of vessels normally requiring a good deal of maneuvering, while the a-c drive will be utilized on vessels requiring a considerable amount of power and infrequent maneuvering.

RUSSIAN CONTRIBUTIONS

Records show that electric propulsion of ships had its beginning more than 100 years ago. The credit for the historic experiment goes to the Russians. In 1839 they built a boat capable of carrying 12 passengers, and propelled by an electric motor supplied with energy from a 69-cell storage battery. Strangely enough, the motor proved to be the weak link, and the experiment was soon forgotten. The next experiment was by the British in 1882, but no details are available. In the period from 1886 to 1888, two British and two French submarines of very small size were built and fitted with electric motors fed from storage batteries. Another experiment in electric propulsion of a surface vessel was made in 1903, again by the Russians. They built a shallow-draft

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Essential substance of an address given before the AIEE, Seattle, Wash.; Portland, Oreg.; San Francisco, Calif.; and Los Angeles, Calif.; Sections.

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tanker for operation on the Volga River. The machinery consisted of three three-cylinder Diesel engines each driving a generator and exciter and three propulsion motors each driving a screw. The control system was of the variable-voltage type. The vessel continued in service until 1913.

THE A-C SYSTEM

The first use of the a-c system of propulsion was in 1910, when the British made an experimental installation on a passenger launch. It had a single Diesel engine driving a special alternator with independent windings for four or six poles and a propelling motor wound for 8 and 12 poles. The motor had a squirrel-cage winding, and bridge control was provided. The same experimenter made another installation in 1913, using two Diesel generating sets and a squirrel-cage-type propulsion motor. The experiment was not very successful, probably because the engines were of insufficient capacity for the propeller and gave trouble with frequent breakdowns. The next development was made in the United States in 1913, when the Navy made an experimental installation on the 5,400 shaft horsepower twin-screw collier "Jupiter." This plant involved two propulsion turbine-generator sets supplying power to wound-rotor induction motors. The success of this installation led the Navy Department to adopt this form of drive on several battleships and aircraft carriers which were then being designed.

Figure 1. Lowering completely assembled propulsion turbine-generator-condenser unit into vessel

In the early development of this type of propulsion, wound-rotor motors, together with the attendant complicated and heavy control, were utilized, along with comparatively slow-speed heavy turbine-generator sets operating at about 30 cycles. Development progressed through the stage of the squirrel-cage motor and finally to the synchronous motor with simplified control and smaller and lighter turbine-generator sets. During the last 15 years, many developments have taken place which have greatly improved this type of propulsion equipment. The art of welding has been utilized to a great extent in practically all parts of the machinery with a considerable saving in space and weight. Methods have been worked out so that the operating speeds of the turbine-generator sets have been materially increased so that some modern units operate at 90 cycles. This has afforded a great saving in space and weight. As in the case of d-c equipment, improvements have been made in the ventilating systems and in the application of insulating materials of higher grade. Through experience, testing, and research, a much better knowledge has been obtained of the actual performance characteristics of propellers and types of vessels, so that the electric equipment can be better designed to fit the actual conditions. In the early installations, the electric equipment was designed with sufficient inherent torque margin to provide stability in the system under maximum conceivable conditions. This meant large and heavy equipment. In recent years, systems have been developed to provide automatic stability control in the electric system so that the overexcitation required during peak-load swings is applied automatically and only during the period needed. This enables the designer to save weight and size on the apparatus. Another means of saving in weight on the machines is the use of dynamic braking to stop the propeller in reversing. By means of suitable resistors and control connections, the return energy of the propeller during reversing is absorbed externally to the machines.

A-C VERSUS D-C SYSTEMS

The a-c equipment is very desirable for electric propulsion from the standpoint of minimum size, weight, cost, maintenance, and simplicity. However, for vessels of relatively small power and special service, these advantages are overbalanced by the greater control flexibility and better performance of the d-c equipment. Thus, a-c propulsion is most adaptable to ships requiring considerable power. With this system there is a fixed ratio between the speed of the prime mover and the propeller—the inverse of the ratio of the number of poles on the generator and motor. Thus, in effect, the a-c drive accomplishes the same results as the use of reduction gears with the added functions of providing for reversal and thus permitting the prime mover to develop full power astern greater flexibility and damping tending to reduce torsional vibration.

The a-c Diesel-electric system is the most recent type to receive serious consideration. Considerable development was carried out in Europe in the period

Figure 2. Pilot house on the *Juniper* showing new-type control desk

from 1936 to 1939, and five vessels were built, the later installations utilizing synchronous motors. Development in the United States started in 1939, when a special plant was installed in a tuna fishing boat at San Diego, Calif. This plant consisted of three Diesel-driven generating units operating on a constant frequency bus which supplied both auxiliary power and power for a tandem arrangement of three wound-rotor induction motors driving the propeller through a reduction gear. The three motors were of different capacity and pole combinations, so that three basic speeds were obtained when operating from the constant-frequency 60-cycle ship's bus. The only other installation in the United States was made in 1941 on a large twin-screw Naval vessel. The plant included two 5,900-horsepower direct-connected synchronous motors and eight Diesel-driven generating sets. Both of these installations have given excellent service, and the experience gained in designing, building, and operating these equipments, leads to the conclusion that these systems are entirely satisfactory for vessels of this class and ships of similar power requirements.

DIFFERENCES IN OPERATION

The a-c Diesel-electric system comprises component parts similar to those of the d-c Diesel-electric drive. However, the operation of the system is entirely different and is comparable with the a-c turbine-electric drive. The fundamental principles of speed control and reversal of the propulsion motor are similar to those described for turbine-electric a-c drives. The main difference is, of course, that with the Diesel-electric system, several prime movers are used which makes necessary the parallel operation of the generator units on the propulsion motor bus over a speed range of about 25 per cent to full speed on the engines and with varying load. Also, means are required for switching and synchronizing the propulsion generators. However, only the actual connection switches are used, as no elaborate synchronizing devices, such as are necessary in a power plant on land, are required.

Because of the limited torque capacity of the Diesel engine at idling speed, special precautions are necessary to control the torque placed on the engines during starting and maneuvering. This takes the form of a simple torque regulator. The engine governors must be specially designed and carefully applied so as to provide very closely the same speed-regulating characteristics.

An examination of the most common form of a-c propulsion reveals this to be the turbine-electric system. Such a propulsion plant would comprise a boiler plant, a single high-speed, variable speed, nonreversible steam turbine driving a direct-connected propulsion generator, a condenser, a propulsion motor, a source of excitation power, control equipment, connecting cables, and certain auxiliaries.

The modern a-c turbine-electric propulsion plant makes use of synchronous generators and synchronous propulsion motors with heavy pole face or damper windings especially designed to provide the necessary maneuvering characteristics. The motor and generator operate at approximately unity power factor over the entire speed load range. Speed control of the propeller is accomplished entirely by varying the frequency, which means varying the turbine speed. The control equipment for this type of propulsion is simple. It provides three main functions:

1. Control of the turbine governor in order to obtain various speed settings, by means of a simple lever and mechanical connection.

2. Connection of the circuit from the motor stator to the generator stator and for interchanging two phases of this three-phase connection for reversal, by means of air-break contactors operated by cams from a lever.

3. Connection of the generator and motor-field circuits to the excitation power source, by means of contactors operated by cams from a lever.

In starting the ship from rest, the turbine speed is adjusted to the idling position, usually about 25 per cent of full speed. The circuit from the motor stator to the generator stator is closed with no excitation on the motor field, which is short-circuited through a fixed resistance, and at the same time the circuit applies heavy overexcitation to the generator field. The motor starts as a squirrel-cage induction motor, operating on the damper windings. It quickly accelerates to a speed nearly synchronous with that of the generator and is then synchronized by applying field excitation to the motor. The generator excitation is then reduced to normal. Excitation power is usually taken from the ship's auxiliary-power bus or from a special exciter driven by the same prime mover which drives the ship's auxiliary-power generator.

By far the greatest number and variety of installations have used d-c transmission. The fundamental reasons for this are found in the inherent characteristics of superior torque performance and greater control flexibility, refinement, and economy of the d-c transmission compared with the a-c system. Part of the greater control flexibility comes about because there is no fixed-speed ratio between the prime mover and propeller as there is with the a-c system, so that the ratio may be adjusted by controlling the excitation of the motor and the generator.

In the most common form of d-c propulsion, namely, the Diesel-electric, the electric drive makes possible the use of several, high-speed lightweight nonreversible engines to drive a single slow-speed efficient propeller. Such a propulsion plant would normally include two or more engine-driven generators, a propulsion motor, a source of excitation power, suitable control equipment, connecting cables, and certain auxiliaries. If applied to a multiple-screw vessel, a similar plant would be provided for each propeller. In some installations two or more motors may be connected to the propeller through gearing. The control system used on most propulsion systems of this type is exceedingly simple, and is known as the variable-voltage system. The generators and motors are of the shunt wound separately excited type with the field excitation supplied from either small exciters driven by the main engines or by the ship's constant-voltage auxiliary-power bus. The propulsion-motor field is excited at a constant value, while the excitation of the generator fields is varied from zero to full value in either direction by means of a simple control device. And so the output voltage of the generators applied to the propulsion motor is simply controlled, thus regulating the speed and controlling the direction of rotation of the motor. On modern installations using high-speed engines, the speed control on the propulsion motor is obtained partly by this variable-voltage control system plus a certain amount of control of the engine speed, which, of course, also affects the generator output voltage.

Figure 3. Two d-c propulsion motors on Diesel-electric lighthouse tender *Juniper*

USE IN UNITED STATES

In the United States the first Diesel-electric installations were made in 1919 and consisted of a yacht and a trawler. These first installations were greatly handicapped by the size and weight of the equipment. The engines were of low speed, 150 to 200 rpm, and of very heavy construction. The electric equipment was largely of cast, heavy construction. On this yacht installation, which was a conversion job, two engine–generator sets were supplied together with a single propulsion motor and control equipment. When it came time for installation, it was found that the equipment was so large and heavy that it could not be gotten into the vessel. Finally, only one engine-generator set was installed, and the generator from the other unit was converted into a propulsion motor. As a result, the motor which was built for the job found itself diverted to some other use on land. In early efforts to develop this form of propulsion, there were many difficult times in trying to convince owners that troubles experienced were not inherent in the electric end of the propulsion system.

The intervening years since the early installations have shown great progress in the application of this form of propulsion, such as:

1. Development of the medium-high-speed engine with rotative speeds of from 400 to 750 rpm.
2. Substitution for heavy cast construction on both engines and electric equipment of welded steel structures, affording greater strength and a great saving in weight and space.
3. Development of suitable speed control for the engines.
4. Development of simplified compact unit cubicle-type propulsion control.
5. Improvement in ventilating systems of the electric equipment.
6. Employment of superior grades of insulation allowing higher operating temperatures and consequent reduction in size and weight.

The first turbine-electric d-c propulsion plant installed in the United States was on a fireboat in Chicago. Other installations, totaling nine, were made on ferryboats, river towboats, and hopper dredges.

In the d-c turbine-electric system, the electric equipment and method of control are exactly the same as for the Diesel system, with the exception that the generator operates at constant speed since this gives the best performance of the prime mover. In this system a high-speed turbine with a reduction gear is substituted for the Diesel engine, and, of course, a boiler plant together with the necessary condenser and auxiliaries is required.

At the present time manufacturers are constantly conducting studies, tests, and research in an effort to improve the equipment and to decrease size, weight, and cost, and to improve performance. It is hoped that this work will produce improved systems. The most hopeful outlook appears to be in the utilization of better materials. These may include magnetic materials, and particularly, better insulation materials such as glass, and the new synthetic inorganic varnishes which will permit operating at considerably higher temperatures than now used. After the war an ample supply of aluminum and magnesium at reasonable cost is looked for which should more extensively reduce weights of equipment. Thus, in the future, it is expected that electric propulsion will be further developed and its use extended more in the next 20 years than it has been in the past quarter century.

Statistical Methods in Quality Control

II. Two Kinds of Measurement—Variables and Attributes

The difference between measurement by variables and measurement by attributes and the use of the arithmetic mean and standard deviation in solving engineering problems are discussed in this article.

BASICALLY, engineering characterizes a natural property or quality by counting or classification on some scale of measurement. When the numerical magnitude of a variable characteristic of some specimen is determined, we employ the *method of variables*. Illustrations are the use of micrometer for measuring a spindle diameter, or a voltmeter for measuring a line potential. In view of the practical restrictions to distinguishing all orders of increments of a continuous scale, the value of any observation is limited by the graduations on the measuring instrument and in essence gives one of a series of discrete values. However, we are dealing with a continuous variable.

When one is examining or testing a specimen for its conformance or nonconformance to a specified requirement, there can be classification into one of two classes only. This is known as the *method of attributes*. Examples are: visual inspection of a spindle for flaws; inspection of a bolt for length, by a go-no-go gauge; testing a dielectric for breakdown at a given voltage. In some cases, attributes results may be used, based upon a variables scale of primary measurement, it being noted whether or not a value falls outside given tolerance extremes or limits. For example, the allowable limits in variation of plate current for an electronic tube may be 10.5 and 12.0 milliamperes. Measurements may be made to a nearest quarter milliampere, but the tube would be recorded only as good or bad.

A common problem is the *collective* characterization of quality of a number of similar specimens in a sample or lot. The two methods would compare as follows:

1. *Method of Variables.* Manifold classification or distribution on a continuous scale. Any single value is designated as (X); the collective quality by a frequency distribution, and/or by such condensation functions or statistics as the average $(\bar{X})$, the standard deviation (σ), described in the following.

2. *Method of Attributes.* Two-way classification as good or bad, with respect to specified requirements. The collective quality is expressed as a number bad (c), or a fraction (p), of the total number of specimens examined or tested (n).

Some quality characteristics can be measured only by the method of attributes; for example a condenser breaks down at a given voltage or it does not, a glass stem is cracked or it is not. In many cases, however, either method may be used, the choice industrially being influenced largely by economy, convenience, and reliability. A comparison of such considerations is given in Table I.

We have seen in the preceding article of this series that repetitive observations vary, given sufficient sensitivity of method, and that a distribution or spread of values is obtained. As quantitative recognition of this variability is necessary in technical projection and inference, we analyze the properties of such distribution. Figure 1

One of a series of articles prepared in the AIEE subcommittee on educational activities and sponsored by the AIEE subcommittee on statistical methods.

Personnel of the AIEE subcommittee on educational activities: J. Manuele, H. F. Dodge, A. I. Peterson, and R. E. Wareham.

illustrates the differentiable characteristics, such as average value or location on the scale, spread or dispersion, and skewness. To condense the information contained in a frequency distribution, we employ certain "statistics" of the collective quality.

The most important function or statistic is usually the *average*, or arithmetic mean, to determine central tendency or position of a group of *n* observations, defined* as

$$\bar{X}=\frac{X_1+X_2+\ldots+X_n}{n}=\frac{\sum\limits_{i} X_i}{n}$$

Of next importance is dispersion or spread of the observations. The statistic preferred, for amount of information contained and for amenability to mathematical manipulation, is the *standard deviation*, σ. It is the rms deviation of the observed values from their average;* that is:

Table I. Comparison of Method of Variables and Method of Attributes

	Variables	Attributes
Time necessary for testing	High	Low*
Skill necessary for testing	High	Low*
Cost of test equipment	High	Low*
Amount and complexity of records	High	Low*
Information per observation	High*	Low

* Generally favorable considerations.

$$\sigma=\sqrt{\frac{(X_1-\bar{X})^2+(X_2-\bar{X})^2+\ldots+(X_n-\bar{X})^2}{n}}$$

$$=\sqrt{\frac{\sum\limits_{i}(X_i-\bar{X})^2}{n}}$$

$$=\sqrt{\frac{\sum\limits_{i}X_i^2}{n}-(\bar{X})^2}$$

Another measure of dispersion, used in small sets of observations, is the Range, *R*, defined as the difference between the largest observed value and the smallest observed value; that is:

$R=X_{\max}-X_{\min}$

The use of a limited number of statistics to condense original data entails slight loss of information. But in view of usually inexact knowledge about any true underlying distribution, the practically essential information from a distribution in engineering problems is provided by the arithmetic mean, $\bar{X}$, the standard deviation, σ, and the number of observations, *n*. In rarer cases, with a large number of observations, a skewness measure is used.

These two functions contain essential information, even if little is known about the functional form of the distribution. Without any reservations as to form, or as to how any set of values was obtained, the use of ($\bar{X}$) and (σ) allows us to say that at least the proportion $(1-1/t^2)$ of the total number (n) of observations lie within the range $\bar{X}\pm t\sigma$, where t is any chosen number of sigmas not less than 1. Thus, if t is taken as 3, the *minimum* is roughly 89 per cent. However, in most cases of engineering data, experience has indicated that well over 96 per cent may be expected in the range of $\bar{X}\pm3\sigma$. This is one of the considerations involved in the choice of three-sigma limits for chance variability in much quality control and other statistical work.

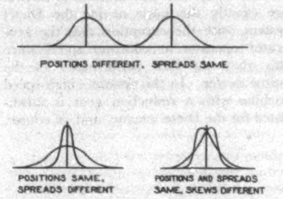
POSITIONS DIFFERENT, SPREADS SAME
POSITIONS SAME, SPREADS DIFFERENT
POSITIONS AND SPREADS SAME, SKEWS DIFFERENT

Figure 1. Characteristics of distribution

A frequency summary for 200 of the afore-mentioned tubes inspected for plate current by the variables method was found to be as given in Table II.

The relationship between the collective quality by attributes and variables methods is further demonstrated. By the former method we would know only that 90 per cent were not outside limits, or at most that 4.5 per cent were too low and 5.5 per cent were too high. By the variables method, we could describe the actual distribution and state that the average was 11.269 milliamperes and the standard deviation was 0.520 milliampere.

It can also be seen, in this more symmetrical case, that plus and minus three standard deviations would include 100 per cent rather than the 89 per cent minimum guaranteed by $(1-1/t^2)$.

Table II. Frequency Summary for 200 Tubes Inspected for Plate Current by Variables Method

Cell Mid-Point Value	Frequency* f	Relative Frequency	
9.75	1	0.005	
10.00	2	0.010	
10.25	6	0.030	
			Lower specification limit
10.50	9	0.045	0.90 or 90 per cent "good"
10.75	23	0.115	
11.00	36	0.180	
11.25	44	0.220	
11.50	35	0.175	
11.75	22	0.110	
12.00	11	0.055	
			Upper specification limit
12.25	5	0.025	
12.50	4	0.020	
12.75	2	0.010	
Total	$f=200=n$	1.000	

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* When n is large, the grouped frequency distribution is used, and the statistics are calculated more easily by the short method found in statistical texts. See reference 1, pages 17–20.

X Rays Alter Wave Length, Change Color of Gems

X rays and other types of radiation, including cathode or electronic rays and deuteron beams from a cyclotron, when allowed to pass through plates cut from crystalline substances, alter the mechanical strength or the material. There are accompanying changes in the color of the crystals, and the chemical reactivity also may be altered.

These discoveries of Clifford Frondel, former senior physicist of the United States Signal Corps and research associate at Harvard University, Boston, Mass., were recently demonstrated at the Reeves-Ely Laboratories, New York, N. Y.

It was explained that the X rays cause an interchange of electrons between the atoms composing the crystal and, by altering the interatomic bonding forces, change the elastic constants of the material. By this irradiation it is possible to regulate the frequency of the quartz crystals used in radio and radar.

Millions of tiny plates of crystalline quartz are used by the armed services as oscillator plates to control radio communications. The frequency at which the radio will transmit or receive is controlled in common types of crystals by the thickness of the plate, brought to proper thickness by a delicate operation. By using the new X-ray irradiation technique, oscillator plates can now be adjusted rapidly and easily to a desired frequency with a precision hitherto impossible.

Another interesting application of X rays is in the altering or the increasing in intensity of gem stones, and some colorless stones of little value may be given intense hues. Diamonds have been colored green and golden brown by irradiation with deuterons.

Irradiation with X rays also has been found to modify greatly the rate of the solution and the chemical reactivity of crystals, a fact which may open up a new field of X-ray photochemistry.

Civic Responsibilities of Engineers

THE ENGINEER, by virtue of his professional standing, has important civic responsibilities, beyond those of the ordinary citizen. For example:

1. Engineering has transformed our ways of living, providing modern conveniences, mechanizing industry, and annihilating distance. These changes have required that vast numbers of people perform highly specialized tasks, making their livelihoods depend on the continued smooth working of both industry and government. Furthermore, with the advance in civilized living, any interruption of public service by wars, depressions, or other disorders, produces a vastly greater human distress.

Therefore, the engineer has an obligation to go beyond his specialized tasks, and do whatever he can to have the best use made of technical knowledge, for the public benefit. The public recognizes the engineer as the agent of economic changes, and looks to him for a remedy whenever technical knowledge is misused, or technical services fail to function.

2. The engineer's training teaches honesty, since he learns that nature cannot be deceived. Also, his experience should develop a co-operative spirit, since engineering projects require that many specialists work in harmony. Thus, the engineer should be thrice fitted to be an instrument of public service, by his technical skill, his adherence to facts, and his experience in organized teamwork.

Professional ethics require that these special abilities be applied for the benefit of the community in which the engineer lives, for the principle of the income tax, whereby the rich give more to the public revenue than the poor, is generally accepted. The same principle suggests that the man with special knowledge or ability has greater civic responsibilities than others.

3. The continuing benefits that will arise from further technical progress, in improving the standard of living, conservation of natural resources, and promoting good will at home and abroad, are dependent on better public understanding of technical problems.

The engineer, therefore, has a responsibility for improving technical education and for aiding the public to understand technical matters of importance to the community.

PUBLIC RELATIONS

The civic actions of engineers may, among other things, consist in:

1. Suggesting that a technical project be considered by the proper authorities.
2. Studying or expounding reports on a project to aid in broadening public understanding of its technical aspects.
3. Recommending individuals qualified for specific appointments; or the employment of competent engineering firms to undertake specific tasks.
4. Educational programs.

Naturally, such recommendations have more value if they express the considered thought of a group, or of a selected expert, rather than the views of a self-appointed critic. An individual may act in a small town, however, with the same effect as a committee in a city, or a section of a national engineering society in a greater area. In any case, the final action is taken by an individual, who is responsible for its technical soundness.

Engineers are well fitted by professional training and experience to take an active part in community and public affairs, but unfortunately they commonly are not inclined to do so. Wider participation of engineers in public affairs is advocated in this article.

The simplest way to be useful in public affairs is to co-operate with the local planning authorities. If there is no city, county, or regional planning commission in existence, an engineer properly may recommend to the public officials that such a commission be formed. If a planning commission exists but is inactive, it is appropriate to recommend some change in the existing law, or the appointment of additional qualified members, that will assist the commission to function effectively.

It is important also that local industry and business have active planning bodies. An engineering society properly may make recommendations to the officials of such groups as the chamber of commerce with even greater force than to public authorities.

When a capable planning commission exists, the chairman may be invited to present to the engineers a résumé of their projects in hand or objectives in view, and the engineers in turn may suggest additional projects for study.

When a project is proposed, individual engineers or committees may study the subject and give the planning commission their suggestions in regard to it, or the employment of qualified engineers to make formal recommendations may be suggested.

When a project is finally decided on by the commission, well-informed engineers may be helpful by addressing civic groups on the technical aspects of the proposal, or otherwise aiding the public to appreciate the questions at issue.

The legal, financial, and political aspects of any public question are often more important than the technical aspects, or harder to decide. The purely technical engineer cannot speak with authority in such matters. To be helpful, he must analyze and present facts, not advocate. His role is that of the expert witness. There are, however, a few engineers with sufficient judgment and breadth of experience to make over-all decisions, and these may be brought in for counsel when the need arises.

To be sure, the engineer is also a citizen, and so has a right to express his opinion on any public matter, but his preference counts no more than that of any other voter. If he allows his personal bias or his self-interest to enter into his factual reports, his testimony is discredited.

INDIVIDUAL RESPONSIBILITY

The practice of professional engineering, which includes all engineering services to the public, is restricted in most states to registered engineers, who have met the requirements of state law. Also, no engineer properly can make a report on which official action is to be taken without accepting full responsibility as an individual.

One principle of success in public relations, therefore, is that any factual reports on public affairs made under the auspices of an engineering society be the responsibility of individual engineers, rather than of the society as a whole. The group may suggest the project, and aid in finding a qualified engineer who will undertake the work. It is his responsibility to perform it in strict accordance with the engineer's code of ethics. The report itself should stand or fall on its own merit. The society, however, may support the conclusions by publishing endorsements of qualified technical committees or by formal organizational approval after due consideration.

In expressing their opinions on any subject, the officers of a national-engineering-society section, or committee, should speak as individuals delegated by their associates to give their views. They should not state or imply that the full membership of their organization sup-

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A report prepared by a joint subcommittee on civic affairs of the AIEE technical program and Sections committees. The subcommittee was formed by joint action of the technical program and Sections committees in April 1944, and was discharged after completing this assignment in December 1944. Personnel of the committee: P. L. Alger, *chairman;* H. W. Bibber, O. C. Brill, M. D. Hooven, A. C. Muir, and C. S. Purnell.

ports these views, because it is impossible for the entire membership to assimilate any one technical subject, even if they were qualified to do so.

THE ENGINEERING METHOD

On the wall of the library in the Engineering Societies Building in New York, N. Y., is this definition:

> "ENGINEERING: The art of organizing men, and of directing and controlling the forces and materials of nature for the benefit of the human race."

Most engineers, while technically expert in a particular field, are not skilled in the art of organizing men, nor can they foretell any better than other men what actions will most benefit people in years to come.

The engineer, however, has a particular virtue besides his technical skill, and that is his training in the engineering method. This method consists in experimenting, observing, and keeping an open mind, so that every proposal will be thoroughly tested before acceptance. Rather than accepting established methods or arbitrary statements, the engineer devises tests to check them.

In the field of human relations, this engineering method requires the democratic spirit of seeking advice from whoever can give it, and continually modifying ideas in the light of experience.

Perhaps the greatest contribution engineers can make in civic affairs is to apply the engineering method of analysis, substituting facts for opinions, and gaining decisions by tests rather than debate. The engineer should seek to impart this method to others, so that they may become more self-reliant, rather than to attempt himself to solve problems beyond his experience. In this way, the engineer will still be "sticking to his last," even though he enters the broad field of civic affairs.

CO-OPERATIVE ACTIVITIES

It is evident from this review that close co-operation between the many types of engineering specialists and the public authorities is desirable in these civic activities. Engineers are specialists, so that only by working co-operatively can they cover the wide range of technical problems that affect the public welfare.

Civic responsibilities are shared in some degree by all men of professional standing. The medical and legal professions have long recognized this, and by organizing co-operatively in county associations have been able to perform creditably many civic tasks. Public officials habitually look to these associations for guidance in the fields of public health and law. Similarly, business men have organized chambers of commerce for co-operative civic actions. Following this trend also, the National Society of Professional Engineers has gained wide recognition as a leader in the organization of engineering talent for public service.

It is, therefore, logical for the engineers resident in any community to form committees, or join forces with other groups to perform these civic duties. How engineers should organize co-operatively in a given community has been discussed on numerous occasions, and trials have been made of many different procedures. This experience was reviewed at an AIEE conference in St. Louis, Mo., in October 1941, and again in New York, N. Y., in January 1942.

CO-OPERATION IN PRACTICE

The general opinion at these conferences, and in discussion elsewhere, has been that co-operation may well be organized through the formation of a local engineering council, or club, or society, composed of representatives of the local chapters of the national engineering societies and other local technical organizations. In this way, the experience of the existing national organizations will be utilized, and the participation of all engineers in the community will be secured.

Based on the reports presented by representatives of active engineering councils of this type and on the discussions at the conferences just mentioned, specific recommendations in regard to the organization, functioning, and activities of a local engineering council were presented by F. A. Cowan, as recorded in *Electrical Engineering* for March 1942, pages 148–9.

In conclusion, engineering results are achieved first by specialized knowledge, and second by organized co-operation. The engineer gains some specialized knowledge in college, and extends it through his daily work, but the organizing skill required for effective co-operation in civic affairs is only learned through years of experience.

It is hoped that the suggestions in this report will inspire engineers to give thought to this important subject, and that they will aid them to be more useful in public affairs.

Scientific Methods in Diamond-Die Production

Small diamond dies, used to draw millions of miles of filament and resistor wires for wartime electronic equipment, are now precision-made by American workers. New scientific methods are used in diamond-die production instead of the previous method of hand-drilling and laborious polishing. Latest electronic developments depend on invisible wires drawn at high speeds through precisely drilled diamonds. Metal strands are drawn through microscopic channels, producing wires some of which are finer than 0.0008 inch in diameter.

SUPERFINE WIRES POSSIBLE

Microscopic drilling through rough one-fifth-carat diamonds provides the mirror-finish channels through which metals of various compositions must travel at high speeds, without breaking, to produce the critical wires demanded by war needs. The superfine wires which are the result of this process are used for electronic devices, or even woven into a "cloth" utilized in the manufacture of high explosives.

The efforts of the War Production Board and associated governmental agencies already assure the quality of the dies that will draw the wires for the vast requirements of the future. Shortly after Government die projects were initiated in late 1941, production stood at 1,200 dies per year, or 100 per month. Total contributions of all domestic die producers in April 1942 amounted to approximately 320 dies per month. These were of the superfine sizes.

Today the small diamond-die industry is on the threshold of inexpensive commercial drilling of diamonds to proper contours through assistance of electri sparks, according to the War Productio Board.

LOWER DIE COST FORECAST

This new method of drilling was developed in research by the Nationa Bureau of Standards and by prominen mineralogists and physicists in industry under the sponsorship of the diamon section through the War Productio Board office of production research an development and the war metallurgy committee of the National Academy o Sciences. The process promises highl significant results; finer dies at lowe prices may soon be available to th wire-drawing industries as a result o American ingenuity superimposed o Old World methods, War Productio Board officials recently declared.

INSTITUTE ACTIVITIES

AIEE Board of Directors Meets in New York

Changes in Section territory and provision for a new technical committee were among the matters discussed at the meeting of the AIEE board of directors held in New York, N. Y., May 29, 1945.

Upon recommendation of the 1945 winter-technical-meeting committee, the board took action approving in principle the proposal that exhibits of electric equipment be held concurrently with national and District technical meetings and authorizing technical meeting committees to co-operate with appropriate organizations in preparing plans for such an exhibit in connection with any national or District meeting, subject to the approval of the board or executive committee.

It was voted to establish a new technical committee on industrial control devices with the following scope of activity, recommended by the technical-program committee:

> "Treatment of all matters in which the dominant factors are the design and construction of, but not the application of, industrial control devices exclusive of circuit breakers, switches, fuses, network protectors, protector relays, supervisory control and automatic railway signaling, which are used in the central-station, communication, and transportation work and which are functions of other designated technical committees."

As a result of a discussion on the scopes of the technical committees, the board took action authorizing a committee to review the technical activities of the Institute and recommend any desirable changes in organization and procedure.

A revised report, dated May 17, 1945, of the committee on collective bargaining and related matters was approved for publication. (See pages 239–45 of this issue.) The board also authorized its release for publication at approximately the same time by other societies and publications. The board expressed its appreciation of the excellence of the report and commended the chairman and the members of the committee for their work.

Upon recommendation of the committee on constitution and bylaws, the following sentence was added to Section 27 of the bylaws:

> "Where by reason of public emergencies the Board of Directors shall deem it wise to do so, it may postpone or omit altogether any of the customary conventions."

This amendment was suggested by legal counsel of the Institute in connection with advice concerning the authority of the board of directors to cancel the annual summer convention, so that there could be no technical claim that the board of directors has not performed its duty to provide for a convention.

In view of the increasing number of instances in which applicants for AIEE membership name members of the board of directors as references, the following resolutions were adopted:

> *Resolved* that the board of directors confirms previous actions by the board of directors and by the board of examiners to the effect that in general it is not desirable for names of members of either board to be offered as references in connection with applications for admission or transfer, and that, in the absence of exceptional reasons for the use of such names, applicants shall be requested to supply other references.
>
> *Further Resolved* that the foregoing resolution be printed as a footnote or otherwise on the application forms.

Upon petition the members of the board present voted unanimously for the election of Charles E. Skinner, a past president of the Institute, as an Honorary Member of the AIEE. Votes from the absent members were obtained by letter ballot, as the election of an Honorary Member must be by unanimous vote of the entire board.

In connection with conferences on Section operation and management planned in all Districts except Districts 3 and 10 in place of the regular delegates' meetings during the summer convention, the board, upon recommendation of the Sections committee, authorized travel allowance for the Sections committee's representatives in Districts 1, 2, 4, 5, 6, 7, 8, and 9 to their respective District meetings; the vice-president and the District secretary in District 10 and the chairmen and secretaries of the Montreal and Toronto Sections to attend the meeting to be held in District 1; and the chairman and the secretary of the Vancouver Section to attend the meeting to be held in District 9.

Upon petition by members of the Illinois Valley Subsection of the Urbana Section, approval by the Urbana Section, and recommendation of the Sections committee, the board authorized the formation of the Illinois Valley Section of the Institute, with territory consisting of 22 counties transferred from the Urbana Section.

Upon recommendation of the Mexico Section, the Sections committee, and the vice-presidents of Districts 3 and 7, the territory of the Mexico Section was transferred from District 3 to District 7.

Suggestions of the Philadelphia Section that special sessions on electronic subjects be provided at national technical meetings and greater consideration be given by future program committees to the subjects of communications and instruments and measurements were referred to the technical-program committee.

The appointment of a representative on the Washington Award Commission for the two-year term beginning June 1, 1945, was referred to the president.

Application, upon recommendation of the committee on research, to the Engineering Foundation for continued support, during the year beginning October 1, 1945, of the work of the Welding Research Council, was confirmed. The AIEE and the American Welding Society are joint sponsors for this work.

Upon recommendation of the chairman of the committee, it was voted to approve the discharge of the Joint Committee on Inter-American Engineering Co-operation.

Approval was given to proposals that the Joint Committee on Economic Status of the Engineer and the Joint Committee on Organization of the Engineering Profession be made special committees of the Joint Conference Committee, the last named consisting of the presidents, immediate past presidents, and secretaries of the Founder Societies and the American Institute of Chemical Engineers.

At the suggestion of Malcolm Pirnie, chairman of the committee, the president was authorized to appoint a representative from the New York City area on the action and advisory committee on construction of the Committee for Economic Development, and Gano Dunn subsequently was appointed.

The board confirmed action of the executive committee in voting unanimously to support endorsement by the American Society of Mechanical Engineers of the name of George Westinghouse for election to the Hall of Fame of New York University.

As Section 37 of the Constitution requires appointment at this meeting of the national secretary of the Institute for the year beginning August 1, National Secretary H. H. Henline was reappointed for the year beginning August 1, 1945.

The board took action removing from the active membership list the names of members in arrears for dues for the fiscal year beginning May 1, 1944, and extended the time for payment of such dues until further action by the board of directors.

The national treasurer presented a report on the financial condition of the Institute for the fiscal year which ended April 30, 1945, and the annual report of the board of directors, prepared under the direction of the national secretary, was approved for presentation at the annual meeting of the Institute in New York, on June 27, 1945.

Monthly disbursements were reported by W. R. Smith, chairman of the Finance Committee, as follows: $33,112.18 in March, $25,460.45 in April, and $30,077.42 in May.

Executive committee action on applications were reported, as follows:

As of March 22, 1945—three applicants transferred to the grade of Fellow; 34 applicants transferred and 33 elected to the grade of Member; 158 applicants elected to the grade of Associate; 99 Student Members enrolled. As of May 1, 1945—one applicant transferred to the grade of Fellow; 21 applicants transferred and 26 elected to the grade of Member; 271 applicants elected to the grade of Associate; 217 Student Members enrolled.

Recommendations adopted by the board of examiners at meetings of April 19, May 17, and May 24, 1945, were reported and approved. Upon recommendation of the board of examiners, the following actions were taken:

7 applicants were transferred to the grade of Fellow; 38 applicants were transferred and 43 were elected to the grade of Member; 310 applicants were elected to the grade of Associate; 190 Student Members were enrolled.

Those present were:

President—C. A. Powel, East Pittsburgh, Pa. *Past Presidents*—N. E. Funk, Philadelphia, Pa.; H. S. Osborne, New York, N. Y. *Vice-Presidents*—M. S. Coover, Ames, Iowa; J. F. Fairman, New York, N. Y.; W. J. Gilson, Toronto, Ont.; R. T. Henry, Buffalo, N. Y.; C. W. Ricker, New Orleans, La.; W. E. Wickenden, Cleveland, Ohio. *Directors*—P. L. Alger, Schenectady, N. Y.; K. L. Hansen, Milwaukee, Wis.; T. G. LeClair, Chicago, Ill.; F. R. Maxwell, Jr., Pensacola, Fla.; M. J. McHenry, Toronto, Ontario, Canada; S. H. Mortensen Milwaukee, Wis.; D. A. Quarles, New York, N. Y.; W. R. Smith, Newark, N. J. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y.

Report of the Board of Directors

THE BOARD OF DIRECTORS of the American Institute of Electrical Engineers presents herewith to the membership its 61st annual report, for the fiscal year ending April 30, 1945. A general balance sheet showing the condition of the Institute's finances on April 30, 1945, together with other detailed financial statements, is included herein. This report contains a brief summary of the principal activities of the Institute during the year, more detailed information having been published from month to month in *Electrical Engineering*.

BOARD OF DIRECTORS' MEETINGS

The board of directors held five meetings during the year, four in New York, N. Y., and one in St. Louis, Mo. Two executive committee meetings were held.

Information regarding many of the more important activities of the Institute which have been under consideration by the board of directors and the AIEE committees is published each month in the section of *Electrical Engineering* devoted to Institute activities.

PLACES VISITED BY PRESIDENT POWEL

Alabama
Alabama Section, Birmingham

California
Los Angeles technical meeting
San Diego Section
San Francisco Section

Connecticut
Connecticut Section, New Haven

District of Columbia
Washington Section

Illinois
Chicago Section

Indiana
Central Indiana Section, Indianapolis
Fort Wayne Section
South Bend Section

Iowa
Iowa Section, Des Moines

Kentucky
Louisville Section

Louisiana
New Orleans Section

Maryland
Maryland Section, Baltimore

Massachusetts
Boston Section
Lynn Section
Worcester Section

Missouri
St. Louis Section

Montana
Montana Section { Butte
Great Falls

Nebraska
Nebraska Section, Omaha

New York
New York Section, New York
Winter technical meeting, New York
Niagara Frontier Section, Buffalo
Rochester Section
Ithaca Section

Ohio
Cincinnati Section
Cleveland Section
Columbus Section
Dayton Section
Toledo Section

Oklahoma
Oklahoma City Section
Tulsa Section

Oregon
Portland Section

Pennsylvania
Philadelphia Section
Pittsburgh Section

Rhode Island
Providence Section

Tennessee
Memphis Section

Texas
North Texas Section, Dallas
South Texas Section, San Antonio

Washington
Seattle Section
Spokane Section

Canada
Toronto Section

Mexico
Mexico Section

ANNUAL MEETING

The annual business meeting of the Institute was held Monday morning, June 26, 1944. The annual report of the board of directors for the fiscal year which ended April 30, 1944, was presented in abstract by the national secretary. In the absence of W. I. Slichter, national treasurer, H. H. Henline, national secretary, presented the treasurer's report. The report of the committee of tellers upon the election of officers for the year beginning August 1, 1944, was presented, and President-Elect Powel responded to his introduction with a brief address. Presentation of national prizes for papers presented in 1943 was made.

In addition to the presentation of the Lamme Medal to Arthur H. Kehoe, vice-president, Consolidated Edison Company of New York, Inc., the Faraday Medal of the Institution of Electrical Engineers, Great Britain, was presented by A. P. M. Fleming, Metropolitan-Vickers Electrical Company, Ltd., Manchester, England, and local honorary secretary of the AIEE for Great Britain, to Irving Langmuir, associate director of research, General Electric Company, Schenectady, N. Y., for "his outstanding contributions to electrical science." The meeting was concluded with the presidential address by N. E. Funk.

NATIONAL TECHNICAL MEETINGS

Three national technical meetings were held during the year, and a brief report on each follows:

Summer Technical Meeting. The 60th summer technical meeting was held in St. Louis, June 26–30, 1944. In addition to the annual business meeting and the conference of officers, delegates, and members, there were 28 sessions and conferences with approximately 90 technical papers and 31 conference papers. A joint luncheon meeting with the St. Louis Electrical Board of Trade featured Lieutenant Colonel T. B. Holliday, United States Army Air Forces, Wright Field, Dayton, Ohio, who gave an address entitled, "Aviation and the Electrical Engineer." The Circle Club of St. Louis sponsored a luncheon with members of the board of directors and headquarters staff as guests.

The general session was a fitting occasion to commemorate three important anniversaries in the electrical-engineering profession—the 60th anniversary of the AIEE, the 100th anniversary of the Morse telegraph, and the 40th anniversary of the International Electrical Congress, which met in St. Louis in 1904. Following the celebration of these anniversaries an address entitled "The Engineer's Present and Future Responsibilities" was delivered by William McClellan, AIEE past president and chairman of the board, Union Electric Company of Missouri, St. Louis. The registration at this meeting was 1,142.

Pacific Coast Technical Meeting. The 32d Pacific Coast technical meeting was held in Los Angeles, Calif., August 29–September 1, 1944, as the Los Angeles technical meeting, with a registration of 561. Because of the wartime situation, this meeting was largely on a local basis, and was devoted predominantly to electric equipment for military aircraft. There were 15 technical sessions on aircraft electrical developments with 58 papers and four sessions on other subjects. In the general session, J. M. Gaylord, vice-president District 8, presided, and the speakers were Brigadier General Donald F. Stace and C. A. Powel, president, AIEE, who spoke on "The Engineer and His Future." At a luncheon meeting Lieutenant Colonel Holliday gave his address on "Aviation and the Electrical Engineer."

Winter Technical Meeting. The 33d winter technical meeting was held in New York, January 22–26, 1945, with a program including 21 technical sessions, at which 80 papers were presented, and ten informal conferences. "Research and Its Effect on Winning the War" was the subject of an address by J. Carlton Ward, Jr., Fairchild Engine and Airplane Corporation, New York, at the general session. Other features of this session were presentation of the Alfred Noble prize to W. R. Wilson, General Electric Company, Schenectady, and presentation of an Honorary Member certificate to Dugald C. Jackson, AIEE past president and professor emeritus of Massachusetts Institute of Technology, Cambridge. A smoker was the only entertainment event. The registration at this meeting was 1,718.

As has been the custom in recent years, a joint evening session was held with the Institute of Radio Engineers, which was meeting concurrently in New York. The first portion of this session consisted of the presentation of the Edison Medal to E. F. W. Alexanderson, consulting engineer, General Electric Company, Schenectady, N. Y. The second portion was an address delivered by Captain J. B. Dow, United States Navy, Washington, D. C., entitled "The Navy Electronics Program and Some of Its Past, Present, and Future Problems."

DISTRICT TECHNICAL MEETING

North Eastern District Technical Meeting In compliance with the recent wartime ban on conventions this meeting, which was

Table I. Section and Branch Statistics

	For Fiscal Year Ending April 30					
	1940	1941	1942	1943	1944	1945
ctions						
umber of Sections	70	72	72	73	73	73
umber of meetings held	701	703	647	598	738	884
otal attendance	91,949	92,554	78,254	66,111	83,120	96,346
ranches						
umber of Branches	121	123	124	125	125	125
umber of meetings held	1,346	1,163	946	942	755	547
otal attendance	64,972	52,285	37,785	38,227	24,768	17,132

cheduled to be held in Buffalo, N. Y., pril 25–26, 1945, was canceled.

SECTIONS

1. *Section Programs.* The Sections genrally have been following a program of arrying on a reasonable amount of activity ich will be most useful to their members nd to their local communities. Considerble effort has been made to retain the iversified interest of the older members, as ell as to attract new and younger members. Iany programs have been devoted to air ansportation, various phases of instrument anufacture and their application, the eory and application of electronics, comunications, and other subjects closely reted to the war effort. In December 1944 letter was sent to all Sections calling atteneon to the advisability of properly expandg Section activities so as to create addional interest in AIEE within the Section rritory. Several methods which are being ost successfully used in this expansion were escribed. It was pointed out that it is excted that the individual Sections will select ose additional activities which will bring to eir Section the greatest benefits for the most onomical expenditure of their available nds.

2. *Sections-Committee Organization.* Beause of the increasing volume of the Sections ommittee work, the committee was organed at the beginning of the year into two oups. The planning group, consisting of x members, initiates and develops all plans the committee. The promotional group onsists of ten members located geographilly on a District basis, making it possible r its members to handle most of the prootional work individually with the Secons. Most of the material used by the romotional group is sent to each member, ho in turn supplements it with his personal nowledge of local conditions before concting the Sections in his District. Close ntact also is maintained between the prootional group member and the vice-presient of the District. It is believed that this ganization provides for closer relations etween District officers and the Sections ommittee.

3. *Section Finance.* In co-operation ith the finance committee of the Institute, ans were formulated to provide certain creases in appropriations to all Sections d additional increases to those operating bsections and technical groups. This new an of Section appropriations was adopted the board of directors at a meeting held November 2, 1944. As a result of these creased appropriations, many Sections ve been able to expand their programs of tivities.

4. *Technical Groups.* The development of technical groups is a very important part of the plan to retain the diversified interest of the older members and to attract new members. As a result of the increased interest in the formation of these groups, the supply of the folder "Technical Groups," which was prepared by the Sections committee in January 1944, was exhausted. A revised edition of this folder was made available for distribution in January 1945. The Sections committee, through its promotional group, is making individual contacts with those Sections where there is a possibility of the successful operation of these technical groups. The possibility of forming groups on electronics, instruments and measurements, and communications have been particularly encouraged in this manner. The sections committee promotional group has also been supplying individual Sections with reports on examples of the successful operation of these technical groups. The value of such groups operated within the Section is becoming more generally recognized throughout the country. The number of these groups in active operation has increased from 27 to 51 during the year and consideration is being given by many Sections to the operation of additional groups.

5. *Co-operation With Other National Committees.* Certain features of the sections committee program have been closely coordinated with the finance committee of the Institute and the national membership committee. The chairman of each national committee has also been contacted in an effort to obtain the co-operation of these committees in giving active support on the development and operation of technical groups within the Sections. The members of these technical committees, working within their individual Sections, can encourage the development of technical groups corresponding to the work of their committees. They can also assist such technical groups with information on suitable programs and other information of an operating nature. In this manner, the technical committees may broaden the scope of their activities and at the same time materially assist on the technical group program of the sections committee. Several technical committees have participated actively in this program during the year, and it is believed that this work of these committees will serve as a pattern for future exploration of this field of committee co-operation, which should prove quite beneficial to the Institute in future years.

6. *Subsections.* Subsection operation is a valuable means of accomplishing a very important objective of the Institute by providing additional meeting places at which papers on electrical-engineering subjects may be presented and discussed. With all the territory in the continental United States allotted to the Sections, the next logical step forward in the development of Section activities is the formation of Subsections or additional centers of electrical-engineering influence. Many opportunities exist for members in remote areas of a Section territory to participate in Section activities through the development of Subsections in these areas. Subsection operation is becoming more popular each year as its advantages are more widely recognized. The number of Subsections in actual operation has been increased from 6 to 12 during the year, and several additional Subsections are in process of being formed. The Sections committee has assembled information on 43 widely distributed locations where the Sections involved are considering Subsection operation. The promotional group of the Sections committee is encouraging Sections to consider the opportunities which exist for the formation of many additional Subsections in cities which are located long distances from the regular Section meeting places. Examples of successful Subsection operation are being furnished individual Sections to give encouragement to this effort. The original Sections committee folder, "Subsections," has been rearranged and completely revised, so that it contains the latest information on the organization and operation of Subsections. This revised folder was made available for distribution in January 1945.

7. *Changes in Section Territory.* The following changes in Section territory were made during the year:

The assignment of the territory of the Canadian Maritime Provinces of New Brunswick, Nova Scotia, and Prince Edward Island to the Montreal (Quebec) Section was approved by the board of directors on May 25, 1944. It is believed that the assignment of this territory to the Montreal Section will lead to subsection operation in each of these Provinces.

Seven counties in the States of Indiana and Michigan in the territories of the Chicago (Ill.), Fort Wayne (Ind.), and Michigan Sections were transferred to the South Bend (Ind.) Section on approval of the board of directors on June 29, 1944. This transfer was made with the approval of all the Sections concerned in order to provide the South Bend Section with a more balanced territory.

Upon the request of a group of members at Lima, Ohio, Allen County, Ohio, was transferred from the territory of the Toledo (Ohio) Section to the territory of the Dayton Section by approval of the board of directors on January 25, 1945. This transfer had the approval of the Fort Wayne Section, and was made because the interests of the group involved were more comparable with the interests of the Dayton Section. It is quite probable that this transfer will result in Subsection operation at Lima.

The transfer of Auglaize County, Ohio, from the territory of the Fort Wayne Section to the territory of the Dayton Section was approved on February 27, 1945, by the executive committee of the Institute. This transfer was made with the approval of the Sections and the vice-presidents concerned, in order to make the territory of the Dayton Section continuous with newly acquired

Allen County. District boundary lines were changed in this transfer by removing Auglaize County from District 5 and including it in District 2.

8. *Simplified Report on Section Activities.* A simplified report form on Section activities was prepared and distributed to all Sections at the close of the season's activities in June 1944. A total of 71 reports were returned. This information was compiled and distributed to all Sections on a consolidated report, which provided an analysis of major activities and organization of all Sections. This report provided much information of value to the new officers in laying out their Section programs for the year. All vice-presidents, District secretaries, and the chairmen of all national committees also were sent copies of this report. Due to the wide acceptance of this report, it is planned to continue this feature at the close of the present operating year.

9. *Section Operation and Management.* Due to the cancellation of the summer technical meeting of the Institute, on account of the war emergency, the usual delegates meetings will not be held this year. Many plans have been considered as a substitute for these delegates meetings. It is recognized generally that any plan arranged will fall short of providing the information, enthusiasm, and inspiration which the delegates gain by the personal contacts made at the delegates meetings. The substitute plan suggests a District meeting in each District, to be held as early in the fall of 1945 as practicable. This should be at least a full-day meeting, with the morning session devoted exclusively to a clinic on Section operation and management. The vice-president of the District would conduct the clinic, and it is planned to have a representative of the Sections committee on hand at each meeting to assist in the discussions. An outline of suggested subjects, together with some information on each of these subjects, is being prepared by the Sections committee as an aid to each vice-president in conducting these clinics. Such a plan will leave the afternoon for the regular business meeting of the District committee. Some Districts also are arranging for the Section at the host city of the District meeting to hold a Section meeting on the evening of the District meeting, so that the visiting delegates could attend. Such a Section meeting would be devoted to subjects which would be most suitable for such an occasion.

10. *Committee Meetings.* As a result of the restrictions on travel, only one meeting of the committee was held during the year. This meeting was held on January 24, in New York during the winter technical meeting with an attendance of 26. At this meeting the entire Sections committee program was reviewed, and plans were discussed for the remaining portion of the year. Minutes of this meeting were distributed to all vice-presidents, District secretaries, and Section chairmen. Due to the nature of the Sections committee work, many of the activities of the committee are conducted by means of correspondence.

STUDENT BRANCHES

Much of the effort of the committee on Student Branches during the current year has been toward modification of the pattern of Student Branch operation. This pattern was one of proved success in normal times, but required revision to meet wartime conditions.

Student Branches, with surprisingly few exceptions, have been able to carry on during this year as in the past, but with activity and procedure limited by the more exacting obligations of Army and Navy training and other war activities. In general, the operations of individual Branches have been reasonably successful and satisfactory.

The principal omission of this year has been that of District conferences, both those held in connection with Institute conventions and independently. At a meeting of this committee, with some 30 present, held on January 23, 1945, during the AIEE winter technical meeting, it was voted after very careful study and discussion to follow the spirit of the Office of Defense Transportation restrictive travel order and to cancel all student conferences, rather than adopt a substitute program, such as that of holding a larger number of smaller gatherings, which came within the numerical limitation of the order. Later, the Institute canceled District meetings, such as that at Buffalo, in connection with which a number of student conferences were to be held.

During the year, this committee has worked with the other founder societies in exchange of information and improvement procedure through a joint committee on student activities, and has co-operated with Engineers Council for Professional Development and Society for the Promotion of Engineering Education as there was opportunity.

Particular effort has been devoted this year to the extension of Student Branch activity to every Student Member, with the slogan: "Every member working on some committee." This has been pushed to the letter devising new committees and activities to make sure that every Student Member has some part to play toward accomplishing the important Institute responsibility of developing leaders—executive as well as technical.

Toward this same end, particular emphasis has been placed on programs sponsored and carried on by the students themselves, with specific recommendations from this committee on possible symposia, joint meetings, discussion meetings under student leaders, and industrial orientation sessions presented by students with auxiliary outside help.

Table I gives information on Branch meetings in the past six years, and Table IV contains data on Student Members in the past seven years.

EMPLOYMENT CONDITIONS

The committee on collective bargaining and related matters completed a comprehensive report which was approved in principle by the board of directors. Its release for publication has been deferred by the committee with the hope that the report might be published simultaneously by several engineering societies.

Three members of this committee represent the Institute on a joint committee on the economic status of the engineer.

General Committees

FINANCE COMMITTEE

During the past fiscal year there has been a substantial gain in revenue as a result of the steady growth of Institute membership and an increasing interest in Institute publications. These important factors, together with others set forth in the detailed financial statements which appear with this report, account for the excess of income over expenditures.

Concessions to members serving in the various branches of the Armed Forces and merchant marine have been more than offset by the increase in dues revenue resulting from membership growth. Inactive status had been arranged on request for 2,259 members as of May 1, 1945, a figure comparable with 1,835 in 1944 and 771 in 1943.

All expenditures have been in accordance with the budget approved by the board of directors for carrying on effectively the activities of the Institute. The continuing favorable condition of finances has permitted assignment of $25,000 to the retirement system for members of the headquarters staff to meet the requirements of an increase in the allowance for prior services. An additional sum of $42,000 was transferred to the reserve capital fund, and $3,268 was placed in the Member-for-Life fund. All of these amounts have been invested in appropriate securities.

Schedule I presents a summary of the securities owned by the Institute and the value of these as of April 30, 1945. It will be noted that approximately 63 per cent of the investments for the reserve capital fund is in United States Government bonds. The market value of other securities is extremely favorable, and the entire schedule has had the continuing approval of investment counsel with respect to both individual items and diversification.

The Institute has for many years adhered to the policy of budgeting Institute expenditures within the total of anticipated revenue, estimated on a conservative basis. This has insured a sound financial condition at all times, exceptionally so at present because of the influence of the increase in membership and other factors previously mentioned. The opportunity thus has been afforded to strengthen the reserve fund and provide for the continuance at a proper level of essential Institute activities in those years when income may be reduced below an essential amount as a consequence of economic conditions or other at present unpredictable developments.

TECHNICAL-PROGRAM COMMITTEE

Technical Meetings. With the cancellation of the spring District meeting, only three technical meetings—the summer, Los Angeles, and winter—were held during the year. The total registered attendance at these three meetings was 3,415, which exceeded the total registration of 3,030 for the three corresponding meetings of the previous year and represents a 12.7-per-cent increase in attendance. More technical papers were presented, and more technical sessions were held than at any time during the past five years. Statistics are given in Table II covering the five-year period. In recognition of the importance of the aircraft industry on the Pacific Coast, the program for the Los Angeles meeting included 15 aircraft sessions and 58 papers on electrical applications to aircraft in addition to four sessions outside the aircraft field. Notwithstanding the limitation on attendance by distant members

Table II. Statistics of Technical Programs for Last Five Years

	For Fiscal Year Ending April 30				
	1945	1944	1943	1942	1941
Number of national technical meetings	3	3	3	3	3
Number of District technical meetings	0	2	2	3	2
Registration at national meetings and District meetings	3,415	3,880	3,497	4,274	4,339
Number of papers presented	250	196	168	182	195
Number of papers recommended for *Transactions*	224	153	141	152	167
Estimated number of pages required for printing papers in *Transactions*	1,286	875*	886*	807*	932*
Average length of papers recommended for *Transactions* (pages)	5.74	5.72	6.28	5.3	5.72
Number of technical sessions	64	53	44	50	46
Number of technical conferences	15	24	24	23	18

* Partly estimated.

imposed by the acute travel congestion, a registration of 561 represented the highest ever obtained for a Pacific Coast meeting.

Wartime Programs. In accordance with the wartime policy adopted by the board of directors, the committee has continued to give preference to papers which aid in the war effort. In addition to the Los Angeles program, the St. Louis meeting program had four aircraft sessions, with 17 papers, and the New York meeting had two aircraft sessions, with nine papers. Of the total number of papers recommended for the AIEE *Transactions* 37.5 per cent were in the field of air transportation.

In the industrial field papers of aid to war work have come to the fore. Some of these papers have dealt with industrial-plant distribution systems and power recovery from airplane-engine testing, electric equipment for the propeller milling machine, industrial control, electric welding, and induction and high-frequency dielectric heating. The latter subject has many wartime applications, particularly in the synthetic products industries.

General Sessions. The general sessions have continued to deal with the broader aspects of the profession, at the summer technical meeting with the commemoration of three important anniversaries, at the winter technical meeting with the effect of research on the war.

Technical Conferences. Although technical conferences held have been fewer than during previous years, several conferences have presented subject matter important in the war effort. At the winter technical meeting, conferences were held on the subjects of wartime practices on distribution systems and their effect on system operation and future designs, air transportation, high-frequency dielectric heating, and high-frequency cables. The latter conference was an all-day meeting sponsored with the co-operation of the Army–Navy Radio-Frequency Cable Co-ordinating Committee, Lieutenant Commander John H. Neher presiding.

Table III. Statistics on Meetings

	Registration Attendance	Number of Papers	Number of Transactions Papers	Estimated Number of Pages	Number of Sessions	Number of Conferences
Technical Meetings						
St. Louis	1,142	89	85	514	21	5
Los Angeles	561	74	60	348	20	
New York	1,712	87	79	424	23	10
	3,415	250	224	1,286	64	15
Aircraft Sessions						
St. Louis		17			4	
Los Angeles		58			15	
New York		9			2	
		84			21	

Per cent aircraft papers recommended for *Transactions* = $\frac{84}{224} = 37.5$

Committee Policies. The cancellation of all Institute and District meetings scheduled in 1945 following the winter meeting necessitated the adoption of a modified plan for the technical programs which normally would have been scheduled for those meetings. Under the new plan papers will be presented by publication with preprints made available and discussion submitted in writing as in the past. The papers for the year will be arranged in three programs for the spring, summer, and fall. The general plan was approved by the executive committee on February 27.

To minimize time and travel the committee has continued the policy of the past year, holding one meeting in the fall and another in the spring. The fall meeting was attended by 79.3 per cent of the committee members or duly appointed representatives, as compared with an attendance of 76.6 per cent for the corresponding meeting of the previous year. Much of the work has been conducted through correspondence.

PUBLICATION COMMITTEE

As in previous wartime years, war problems continued to hold first place in the Institute's technical publications during the year. Expected developments in the postwar period also received attention through the medium of a special series of articles appearing monthly in *Electrical Engineering*, beginning with the May 1944 issue and continuing through the entire year. Publication policies and procedures remain unchanged. Although the wartime ban on meetings, which became effective February 1, 1945, will have considerable influence on the handling of technical-program papers and discussions, it necessitated no change in publication procedure, and publication of this material will continue as scheduled insofar as approved papers and discussions are available.

Restrictions on magazine paper continued as in the preceding year, allowing the use in *Electrical Engineering* of 75 per cent (on a tonnage basis) of the paper used during the calendar year 1942, plus a token increase in quota of four tons annually granted by the War Production Board in June 1944 (present annual quota with this increase—112 tons). Further restrictions were imposed which resulted in the use of a lighter-weight paper. This lighter stock, of course, allows more pages of material to be published within the same tonnage limitations. The following tabulation shows the approximate number of words published in the three major divisions of *Electrical Engineering* during the years 1940–44.

Year	News	General-Interest Articles	Transactions Sections (Technical Papers)
1940	332,000	275,000	587,000
1941	426,000	296,000	517,000
1942	445,000	270,000	653,000
1943	357,000	266,000	546,000
1944	323,000	265,000	702,000

In accordance with present publication policies, the 1944 *Transactions* volume contains all approved 1944 technical papers and related discussions. Two semiannual "Supplements to *Electrical Engineering*—Transactions Section" were produced, on the usual limited-edition advance-order basis, containing

1. Technical papers that could not be accommodated in the monthly Transactions sections of *Electrical Engineering*.
2. All approved discussions.

The greatly expanded technical-paper program during 1944 required publication in the *Transactions* of a correspondingly expanded amount of papers and discussions. The total number of *Transactions* pages for the year was 1,558 as compared with 1,044 for 1943. Of this total, 1,272 pages were technical papers, 778 pages of which were included in the 12 monthly Transactions sections of *Electrical Engineering;* comparable figures for 1943 were 816 and 634 pages, respectively. Thus, the proportion of the year's technical-program papers included in *Electrical Engineering* in 1944 was less than in previous years, although more pages of such material were published therein than in previous years.

After an attempt to obtain a substantially increased quota of magazine paper in order to include more of the 1944 technical papers in *Electrical Engineering* had failed several additional economies in the use of paper were adopted. In the general section, the size of type was reduced and a three-column format adopted in place of the former two-column arrangement. At the same time, in the Transactions section the spacing between lines was reduced. It is believed that these economies will not impair seriously the readability of the material.

As an additional measure to conserve magazine paper, the annual index pamphlet for 1944 (covering both *Electrical Engineering* and *Transactions*) was not published as a second section of one of the monthly issues. Copies of the index were distributed to all members of all technical committees and to all subscribers to both *Electrical Engineering* and the supplements. Copies were made available to all others without charge upon written request.

Advance pamphlets of approved technical papers were produced as required by the technical-program committee for the national and District meetings held during the year and for discussion by mail during the spring of 1945 after the cancellation of meetings. The booklet, "Information for Authors," was reprinted, the previous supply having become exhausted. Although the present edition is somewhat out of date, revision was deferred so as to avoid having the booklet out of stock over an extended period. Revision is planned within the next year.

Publication of the quarterly AIEE *Bulletin* for Institute members in the armed services and the merchant marine, initiated in June 1943, was continued throughout the year. This consists of a four-page pamphlet and includes news of the Institute and related items that are considered of interest to these members. More than 2,000 copies of each issue now are being produced and distributed to members on all the fighting fronts.

Governmental censorship regulations were maintained during the year, although the procedure was changed. The censorship regulations now are applied entirely on a voluntary basis by the staff, and only material that is considered censorable is submitted to the Office of Censorship for advance review. Advance proofs of publications intended for export no longer are required, although all publications exported still are subject to inspection by the postal censors. As in the past, full co-operation has been extended to, and has been received from, the Office of Censorship.

MEMBERSHIP COMMITTEE

The Institute membership has continued its upward trend, and attained a total of 23,072 as of April 30, 1945. This compares with a total of 21,407 as of April 30, 1944. A net increase of 1,665 has been obtained in comparison with the net increase in 1943–44 of 1,246, and it is the largest increase in any one year in the history of the Institute with exception of the year 1920–21.

A total of 2,259 persons now are maintaining an "inactive status" because of military service or residence in Allied countries with which financial transactions are difficult. This is an increase of 424 over that of last year. There are, however, only 902 members in arrears for dues for the fiscal year ending April 30, 1945, as against a total of 1,288 last year. Incidentally, this is the lowest number of members in arrears at the end of any fiscal year for over 18 years and represents only 3.8 per cent of the total membership.

Tables IV, V, VI, VII and VIII outline certain statistical data relative to membership matters.

Table IV gives the data relative to the various grades of membership in the Institute, the additions, the deductions, and the net changes for the year 1944–45. In every instance, with the exception of the matter of deaths, the figures are on the favorable side. The number of members dropped represents a decrease of 323. The number of those reinstated or re-elected represents a gain of 65. The number of new members qualified represents a gain of 29. The number of transfers represents a gain of 88. The membership is divided as follows:

Member Grade	Per Cent
Honorary	0.03
Fellow	3.96
Member	27.03
Six-Year Associate	30.19
Associate	38.79
	100.00

The Member and Associate grades have increased 0.73 and 0.39 per cent, respectively, while the six-year Associate and Fellow grades have decreased 1.01 and 0.11 per cent, respectively. The six-year Associate grade of membership continues to be a large source of possible transfer to Member grade.

Table V shows a decline in applications from "Student Members" which is continuing as against the upward trend in applications from "All Others." No direct comparison between this table and Table VI can be made, since not all applications received during the fiscal year are acted upon before the close of the fiscal year.

Table VI gives the data on the number of applications received for Student membership. Prior to 1945, this group was known as Enrolled Students. It will be noted the "New Applications" have started an upward trend and that there has been a marked reduction in the downward trend of "Renewals." These favorable results were entirely unexpected.

Table VII is a record of the total membership of the Institute by years since 1884 and is given for information purposes.

Table VIII is the customary listing of the deaths of AIEE members as reported in *Electrical Engineering*. By this means the membership committee makes a record of the completed careers of those members taken from the ranks by the Great Reaper.

The preparation of additional material for use by the membership committee generally in interesting persons in membership in the Institute is being undertaken. This is the result of information obtained from various sources indicating a need in that direction.

As a result of requests from Section membership committee chairmen and others, a plan was introduced for sending a reprint

Table IV. Membership Statistics for Fiscal Year Ending April 30, 1945

	Honorary Members	Fellows	Members	Six-Year Associates	Associates	Subtotals	Totals
Membership April 30, 1944	6	872	5,632	6,659	8,238		21,407
Additions							
New members qualified			252		1,749	2,001	
Former members reinstated or re-elected		1	139	83	143	366	
Subtotals		1	391	83	1,892	2,367	
Transfers	1	67	396	873		1,337	
Totals	1	68	787	956	1,892	3,704	
Deductions							
Died	1	19	44	52	10	126	
Resigned		3	19	59	42	123	
Dropped		3	51	189	210	453	
Subtotals	1	25	114	300	262	702	
Transfers		1	67	352	917	1,337	
Totals	1	26	181	652	1,179	2,039	
Net changes		42	606	304	713	1,665	
Membership April 30, 1945	6	914	6,238	6,963	8,951		23,072

Table V. Number of Applications Received From Student Members and From All Others

Year Ending April 30	Students	All Others	Tota
1945	249	2,179	2,42
1944	466	1,908	2,37
1943	783	1,431	2,21
1942	971	1,031	2,00
1941	887	1,011	1,89
1940	911	918	1,82
1939	849	872	1,72

Table VI. Number of Student Members as of April 30

Year	New Applications	Renewals	Tota
1945	2,326	2,287	4,61
1944	2,242	2,656	4,89
1943	2,512	3,200	5,71
1942	2,585	3,377	5,96
1941	2,351	3,188	5,53
1940	2,525	2,992	5,51
1939	2,271	2,971	5,24

Table VII. Record of AIEE Membershi

Year	Total May 1	Year	Total May 1	Year	Tota May
1884	71	1905	3,460	1925	17,31
1885	209	1906	3,870	1926	18,15
1886	250	1907	4,521	1927	18,34
1887	314	1908	5,674	1928	18,26
1889	333	1909	6,400	1929	18,13
1890	427	1910	6,681	1930	18,00
1891	541	1911	7,117	1931	18,33
1892	615	1912	7,459	1932	17,55
1893	673	1913	7,654	1933	17,01
1894	800	1914	7,876	1934	15,23
1895	944	1915	8,054	1935	14,26
1896	1,035	1916	8,202	1936	14,60
1897	1,073	1917	8,710	1937	15,30
1898	1,098	1918	9,282	1938	16,07
1899	1,133	1919	10,352	1939	16,60
1900	1,183	1920	11,345	1940	17,21
1901	1,260	1921	13,215	1941	17,88
1902	1,549	1922	14,263	1942	18,94
1903	2,229	1923	15,298	1943	20,16
1904	3,027	1924	16,455	1944	21,40
				1945	23,07

of the postings in *Electrical Engineering* to each applicant for membership whose name appears therein, together with a statement from the membership committee outlining the time elements to be expected prior to the taking of final action on the application by the board of directors. This plan, while introducing some additional expenditure for membership activity, is considered to be justified, since the applicant is kept informed of the progress of the application and a record of the actual posting of applicant's name is given the applicant.

These membership data are almost entirely without an unfavorable aspect. It is for that reason that there is a considerable degree of satisfaction in presenting them. All of this has been made possible by the splendid response from the individual members of the Institute, the intensive continuous effort of the Section membership committee personnel, the membership committee District vice-chairmen, and the other members of the national membership committee.

BOARD OF EXAMINERS

The board of examiners held 12 meetings during the past year, averaging about 2$\frac{3}{4}$ hours each, and acted upon 4,693 cases divided as shown in Table IX. The number of cases for both direct admission and transfer to Member and Fellow grades has been showing a steady increase during the past two years, the increase being 28 per cent in 1943–44, and 23 per cent this past year.

In 1943 a subcommittee was appointed to study the constitutional requirements for Fellow grade. Following conferences with the committee on constitution and bylaws, which also had those requirements under consideration, a final report was submitted this year and approved by the board of directors. The recommendations are now out to letter ballot of the membership. As finally submitted, no changes in substance of requirements are recommended, the proposed alterations and rearrangements of wording being for clarification only.

COMMITTEE ON MEMBERS-FOR-LIFE FUND

This committee was authorized by the board of directors in January 1944, and appointed by the president, to administer the fund established at the same time by turning into it all monies received from the members for life who voluntarily continue to pay their accustomed annual dues, even though no longer obligated to do so. The fund and its proceeds are to be used only for such special purpose or purposes as will aid the attainment of the objectives of the Institute.

After considering many possible applications of this fund, the one finally agreed upon was the payment of the expenses to the summer convention of the winners of the District awards, formal announcement of the details of which was made in the February 1945 issue of *Electrical Engineering*.

COMMITTEE ON CONSTITUTION AND BYLAWS

During the year the committee submitted a number of proposals for amendments to the constitution and to the bylaws. On June 29, 1944, the board of directors approved an amendment to the constitution eliminating the word "national" from the titles of officers and names of committees and meetings wherever it occurred.

On January 25, 1945, the board of directors approved amendments to the constitution

1. **Improving the wording of Article III, Section 10, as regards references for an applicant for admission or transfer.**
2. **Clarifying and putting in more concise wording Section IV, Article II, covering the requirements for the grade of Fellow.**

At the January 25, 1945 meeting, the

Table VIII. Deaths of AIEE Members Reported in "Electrical Engineering"

Name	Date of Election	Date of Death	Grade at Death	Obituary Notice in "Electrical Engineering"
Albert, J. C.	A '10	Jan. 16, '45	M	Apr. '45, p. 164
Armstrong, A. H.	A '98	May 31, '44	M	Aug. '44, p. 317
Atkins, C. G.	A '01	Oct. 20, '44	M	Feb. '45, p. 78
Ball, J. D.	A '11	Feb. 10, '45	F	Apr. '45, p. 163
Ballantine, Stuart	M '42		M	Oct. '44, p. 386
Behr, Leo	A '29	June 25, '44	A	Dec. '44, p. 450
Bergman, S. R.	A '04	Nov. 25, '44	A	Jan. '45, p. 41
Betts, Philander	A '96	Feb. 6, '45	F	Mar. '45, p. 126
Binford, J. T.	A '23	July 10, '44	A	Oct. '44, p. 386
Bliss, W. L.	A '94	Dec. 5, '44	F	Feb. '45, p. 78
Braden, N. S.	A '09	Sept. 27, '44	M	Dec. '44, p. 450
Brown, H. A.	A '16	Feb. 25, '45	M	Apr. '45, p. 163
Campbell, John	A '04	Mar. 6, '44	A	May '44, p. 193
Cansfield, C.E.	A '25	July 23, '44	A	Sept. '44, p. 343
Carpenter, L . S	A '20	Apr. 20, '44	A	July '44, p. 272
Coffin, Leroy	A '37	Nov. 16, '44	M	Feb. '45, p. 78
Cole, C. E.	A '27	Mar. 19, '44	A	July '44, p. 272
Conrad, L. L.	A '36	Apr. 6, '44	M	July '44, p. 272
Copeland, C. A.	A '97	Aug. 18, '44	F	Nov. '44, p. 415
Cox, E. H.	A '41	July 6, '44	A	Oct. '44, p. 386
Crumley, T. R.	A '19	Oct. 5, '44	A	Feb. '45, p. 78
Darrall, S. S.	A '41	Sept. 1943	A	July '44, p. 271
Davis, C. M.	A '43	Apr. 27, '44	A	July '44, p. 272
Dey, N. A.	A '36	Aug. 8, '44	A	Nov. '44, p. 416
Downing, P. M.	A '98	Dec. 11, '44	F	Feb. '45, p. 77
Edwards, J. B.	A '29	Feb. 5, '44	A	May '44, p. 193
Eglinton, W. M.	A'03	Aug. 4, '43	A	July '44, p. 271
Elliott, D. A.	A '28	July 31, '44	A	Sept. '44, p. 343
Escher, Henry	A '37	June 16, '44	A	Dec. '44, p. 450
Fuqua, H. E.	A '42	Feb. 23, '44	A	Oct. '44, p. 385
Gardner, J. H.	A '25	Oct. 11, '44	M	Dec. '44, p. 450
Gill, J. H.	A '12	June 16, '44	A	Aug. '44, p. 317
Gabel, F. C.	A '05	Sept. 16, '44	A	Mar. '45, p. 127
Grant, L. T.	A '99	July 15, '44	M	Nov. '44, p. 415
Gray, C. D.	A '02	Mar. 29, '44	F	May '44, p. 193
Green, D. C.	M '26	July 2, '44	M	Nov. '44, p. 416
Greene, C. E.	M '31	Mar. 8, '44	M	May '44, p. 193
Gremillion, B. X.	M '41	May 28, '44	M	Aug. '44, p. 317
Henry, Maxwell	M '32	Apr. 7, '44	M	June '44, p. 236
Hjort, Alf	M '21	Dec. 12, '44	M	Feb. '45, p. 77
Hough, H. W.	A '08		M	June '44, p. 236
Hubbard, F. A.	M '23	Nov. 6, '44	M	Jan. '45, p. 41
Huber, H. L.	M '23	Feb. 4, '45	M	Mar. '45, p. 126
Hubley, G. W.	A '94	Apr. 8, '44	F	June '44, p. 236
Hughes, G. A.	A '17	Sept. 9, '44	A	Mar. '45, p. 127
Humm, D. L.	A '41	Apr. 10, '44	A	July '44, p. 272
Hurlbert, F. W.	A '04	Dec. 4, '44	A	Feb. '45, p. 78
Jackson, W. A.	A '18	June 1, '44	M	Aug. '44, p. 318
Jeffery, J. A.	M '20	Dec. 26, '44	M	Feb. '45, p. 77
Karle, R. D.	A '40	July 27, '44	A	Oct. '44, p. 386
Kay, W. deY.	A '16	Jan. 31, '44	A	July '44, p. 272
Kelsch, R. S.	A '02	Feb. 4, '45	F	Apr. '45, p. 163
Levy, C. C.	A '33	June 5, '44	A	July '44, p. 272
Lewis, D. L.	A '25	July 28, '44	A	Oct. '44, p. 386
Lincoln, P. M.	A '95	Dec. 20, '44	F	Feb. '45, p. 76
Louttit, W. C.	M '31	July 9, '44	M	Sept. '44, p. 343
Lovewell, E. B.	M '43	Nov. 1943	M	July '44, p. 272
Manson, G. K.	A '09	Jan. 6, '45	F	Apr. '45, p. 163
Marshall, A. C.	A '14	Feb. 9, '45	F	Apr. '45, p. 163
Merrick, F. A.	A '07	Oct. 26, '44	A	Dec '44, p. 450
Meyer, J. F.	A '08	Oct. 30, '44	M	Mar. '45, p. 126
Mowbray, W. J.	A '03	July 4, '44	F	Sept. '44, p. 343
Newman, W. L.	M '35	Oct. 31, '44	M	Feb. '45, p. 78
Northup, V. E.	A '39	Feb. 4, '44	A	June '44, p. 236
O'Donnell, C. E.	A '32	Oct. 3, '44	A	Dec. '44, p. 450
Oklund, A. L.	A '35	Aug. 19, '44	M	Nov. '44, p. 416
Pearson, E. R.	A '06		M	June '44, p. 236
Peterson, J. A.	A '37	July 13, '44	A	Oct. '44, p. 385
Pierce, D. A.	A '21	June 28, '44	M	Oct. '44, p. 386
Powell, F. H.	A '08	Dec. 11, '43	A	May '44, p. 193
Pratt, L. W.	A '38	Oct. 3, '44	A	Dec. '44, p. 450
Price, R. D.	A '44	June 24, '44	A	Sept. '44, p. 343
Osborne, L. A.	A '93	Aug. 18, '44	F	Oct. '44, p. 386
Randall, K. C.	A '02	Dec. 4, '44	M	Mar. '45, p. 127
Reber, H. L.	A '03	Nov. 1, '44	F	Jan. '45, p. 41
Roberts, C. J.	A '22	June 26, '44	A	Dec '44, p. 450
Rosenthal, L. W.	A '02	Jan. 8, '45	F	Feb. '45, p. 77
Sands, H. S.	A '06	Dec. 13, '44	M	Feb. '45, p. 77
Sanford, W. J.	A '23	Dec. 23, '43	A	July '44, p. 272
Schattner, Ernest	A '06	Feb. 13, '44	M	May '44, p. 192
Schoonmaker, C. F.	A '12	Feb. 20, '44	M	May '44, p. 192
Schou, Theodore	M '14	Nov. 16, '44	M	Feb. '45, p. 78
Scott, C. F.	A '92	Dec. 17, '44	HM	Jan. '45, p. 41
Sinks, A. T.	A '36	Aug. 3, '44	M	Oct. '44, p. 386
Skone, R. C.	A '19	Aug. 14, '44	M	Oct. '44, p. 386
Smith, H. L.	M '36	Apr. 7, '44	F	July '44, p. 272
Smith, J. B.	A '24		[illegible]	June '44, p. 236
Stockman, E. O.	A '39		A	Dec. '44, p. 450
Tadlock, W. L.	A '29	Nov. 27, '44	M	Feb. '45, p. 77
Teach, F. A.	A '24	Oct. 25, '44	M	Feb. '45, p. 78
Teker, Louis	A '26	June 11, '44	A	Aug. '44, p. 318
Tower, L. W.	A '36		A	Nov. '44, p. 416
Troy, M. O.	A '08	Mar. 13, '44	M	May '44, p. 192
Turnock, H. C.	A '16	June 4, '44	M	Oct. '44, p. 385
Varney, Theodore	A '05	Oct. 2, '44	A	Feb. '45, p. 78
Vergilio, J. L.	A '41	Oct. 17, '44	A	Mar. '45, p. 127
Warren, H. M.	A '03	Feb. 3, '45	A	Apr. '45, p. 163
Whitaker, S. E.	A '96	Aug. 10, '44	M	Nov. '44, p. 415
Willison, J. W.	M '26	Dec. 16, '44	M	Mar. '45, p. 127
Wilson, A. M.	A '09	Aug. 23, '44	M	Mar. '45, p. 127
Winslow, C. G.	A '02	Mar. 9, '44	A	May '44, p. 193
Wood, H. G.	A '23	Apr. 4, '44	M	June '44, p. 236
Woodward, A. C.	A '18	July 17, '44	A	Oct. '44, p. 386
Wright, M. L.	A '25	Aug. 9, '44	A	Nov. '44, p. 416

board of directors also approved the following amendments to the bylaws

1. Sections 51, 52, 53, 54, 55, 56, 57, 60 and 64, changing the designation "Enrolled Student" to "Student Member."

2. Section 65, changing the title of "committee on electrical machinery" to "committee on electric machinery" to conform to the American Standard, "Definitions of Electrical Terms."

The committee has under consideration a proposal for amending Section 51 of the bylaws to define "a university or technical school of recognized standing" in terms of the ECPD accrediting program.

The committee also is considering the matter of amending Section 27 of the bylaws to give the board of directors proper backing for its action in eliminating the 1945 summer meeting at the request of the Office of Defense Transportation.

COMMITTEE ON PLANNING AND CO-ORDINATION

The most important matter on which this committee took action was that brought about by the request of the Office of Defense Transportation that all conventions or meetings at which the out-of-town attendance would be greater than 50 people should be canceled, unless the war effort would be injured by the elimination of the meeting. After thorough consideration of all the activities affected, the committee was unanimous in recommending to the board that both the summer technical meeting and the North Eastern District meeting be canceled. This action was taken with the understanding that the technical committees would continue to secure papers, publish preprints, and obtain discussions so that the technical work of the Institute could be carried forward in much the same manner as though the papers actually would be presented in fact. Because of the possibility of change in conditions, the committee did not recommend the cancellation of the Pacific Coast technical meeting.

The board of directors referred to this committee the problem of obtaining more satisfactory publicity for Institute activities. Due to its action in recommending the cancellation of meetings, the committee considered it unwise to attempt to pursue this subject any further at present and recommended to the board that the matter be held in abeyance until conditions were more favorable.

The finance committee presented a resolution which was suggested for adoption by the board of directors to extend the period for Student Members in the Armed Forces and the merchant marine to continue on the inactive basis, which was to replace a similar resolution expiring January 28, 1945. The committee unanimously voted to recommend the adoption of this resolution to the board.

The board took affirmative action on all the recommendations of this committee except that for the Pacific Coast technical meeting, which was referred to the executive committee for further action.

COMMITTEE ON RESEARCH

Research under the auspices of the committee on research continues to be hampered by the fact that substantially all of the research facilities normally devoted to fundamental projects which would usually be fostered by this committee still are devoted to urgent war projects arranged by Government war agencies. The activities of the committee therefore are devoted largely to the preparation of a postwar research program which could be put into effect rapidly, as soon as normal conditions are restored. All the AIEE technical committees are informed of this program, and suggestions have been requested. Information on the procedure by which projects are formulated and presented to the Engineering Foundation for sponsorship and support was given to the technical committee representatives.

At the January meeting of the committee on research, it was recommended that the lists of research projects prepared in 1934, 1935, and 1937 be brought up to date with the revisions of the original subjects to take account of the progress made in the meantime and new projects added as suggested by present knowledge. It was proposed further that these lists be given broader circulation by having them distributed not only to heads of engineering departments in the colleges but also by sending them to engineering experiment stations and commercial and industrial research stations, which are frequently desirous of undertaking research on fundamental problems. Copies also should be available to interested persons other than those listed, and notice of the availability of the lists should be published in *Electrical Engineering*.

COMMITTEE ON SAFETY

Two meetings were held by the committee on safety during the past year, the first of which was a breakfast meeting during the summer technical meeting in St. Louis on June 26, 1944. At this meeting emphasis was placed on the importance of the committee's efforts to promote interest in safety educational work and safety procedure in the Student Branches, and steps were taken to bring together the points of view of the Counselors and others who might give helpful suggestions in this connection. Professor Albrecht Naeter accepted sponsorship for this activity and subsequently submitted a report which will be used in carrying the matter forward. There was a general discussion of the following items:

1. Electrical hazards to farm animals, on which W. B. Buchanan, a member of the committee on domestic and commercial applications, was submitting a paper at the June 29 session.

2. Static electricity, on which subject the committee will at an appropriate time arrange for a conference discussion at a technical meeting.

3. The report on fatalities in the electric-light-and power industry as prepared by the Edison Electric Institute accident prevention committee.

The chairman called attention to the report which was made by the conference committee on operating-room hazards of the National Fire Protection Association to the 48th annual meeting of that association held in Philadelphia, Pa., May 8–11, 1944. This report appears on pages 74 to 88 in part 2 of the *Quarterly* of the NFPA dated April 1944. W. Weinerth represented the chairman at this meeting.

The second meeting was held during the winter technical meeting in New York, on January 23, 1945. Thirty-seven members and guests were present. At this meeting, Cecil K. Drinker, professor of physiology, School of Public Health, Harvard University, presented an important discussion of the subject "The Use of Drugs in Resuscitation from Electric Shock." C. F. Dalziel, a member of the committee, and now technical aid, National Defense Research Committee, summarized for the committee the research work on electric shock carried on under his direction at the University of California, Berkeley. There was a general discussion of the subject of grounding of circuits operating at voltages in excess of 150 volts from the standpoint of hazard to personnel. The chairman announced that arrangements had been made with the editor of *Electrical Engineering* to have a news column appear under the heading "Safety Notes" whenever suitable material was available, with the expectation that this eventually would be a regular feature.

Table IX. Applications for Admission and Transfer, 1944–1945

Applications for Admission		
Recommended for grade of Associate	1,682	
Re-elected to the grade of Associate	140	
Not recommended	2	
		1,824
Recommended for grade of Member	353	
Re-elected to the grade of Member	27	
Not recommended	65	
		445
Applications for Transfer		
Recommended for grade of Member	419	
Not recommended for grade of Member	15	
		434
Recommended for grade of Fellow	63	
Not recommended for grade of Fellow	0	
		63
Students		
Recommended for enrollment as Students		1,927
Total		4,693

The annual meeting of the National Fire Waste Council which was held in Philadelphia on April 13 was attended by R. L. Lloyd, who represented the chairman and the Institute. The appointment of an official executive committee of the Council was authorized. The committee on safety will consider ways in which it may be helpful in promoting the Council's objectives and will submit suggestions through the Institute's representatives.

Standards

STANDARDS COMMITTEE

Due to restrictions placed on wartime travel, the Standards committee held only two meetings. The work of the committee itself, as well as its many co-operating committees and subgroups, however, has been prosecuted actively by correspondence and by conferences of local groups.

An indication of the widening scope of AIEE standardizing activities is illustrated in the list of the following projects appearing on the standards agenda since the last report: "Guiding Principles for the Specifications of Service Conditions," "Guiding Principles for the Selection of Test Voltages," "Test Code for Low-Frequency, D-C, and Impulse Testing," "Preferred Standards for Large 3,600 Rpm Condensing-Type Turbine Generators," "Standard Specifications for Generators for Large 3,600 Rpm Condensing-Type Turbine Generators," and, finally, standardization of aeronautical electric equipment.

Among the AIEE and American standards, revisions of which were consummated during the year, were: "Automatic Stations," "Lightning Arresters," "Insulator Tests," "Fuses Above 600 Volts," "Test Code for Synchronous Machines," and "General Standards for Wires and Cables."

Due largely to shifts brought about by wartime conditions, it has been necessary to make a large number of new appointments of Institute representatives serving on various sectional committees of the American Standards Association.

Participation by the Institute in the development of fundamental electrical standards in the aeronautical field is rapidly going forward under the control of the committee on air transportation, and guidance of an Institute liaison representative, with such other interested groups as the Society of Automotive Engineers, the National Aircraft Standards Committee, the Army Air Forces, the Bureau of Aeronautics, and National Electrical Manufacturers Association. Several subcommittees of the committee on air transportation are projected, and one of these on aircraft electric rotating machinery has completed a proposed standard which is now in process of publication.

In view of the widespread interest in the subject of application of statistical methods in engineering and manufacturing, the Standards committee appointed a subcommittee to explore the possible applications in the Institute's field and to ascertain the reaction of the membership.

In order to reach a conclusion, the subcommittee has set down a plan of work for the coming year embracing the following activities:

1. An educational program including:

(*a*). A series of short technical articles developing the subject from first principles.

(*b*). Articles describing special applications of statistical methods.

(*c*). The sponsoring of conferences and technical sessions and of the presentation of papers at Section, District, and national meetings.

(*d*). General articles addressed primarily to executives, pointing out the advantages of statistical methods.

2. A study of applications in Institute test codes and Standards.

3. Applications in the electrical utility fields.

4. Co-operation with Joint Committee on Application of Statistical Methods in Engineering and Manufacturing.

5. Keeping in touch with developments in which the Institute might properly co-operate.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

During the past year, as in the preceding war years, the work of the International Electrotechnical Commission and the United States National Committee has remained in a state of suspension. It is not contemplated that work will be resumed until after the peace is concluded.

At its annual meeting on November 10, 1944, the United States National Committee re-elected E. C. Crittenden, president; L. F. Adams, vice-president; and H. S. Osborne, vice-president and treasurer.

During the year there was set up a United National Standards Co-ordinating Committee, with the national standardizing bodies of Great Britain, Australia, Canada, New Zealand, South Africa, Brazil, China, France, and the United States as members. Offices have been set up in London, England, under the direction of C. Le Maistre, who is also general secretary of the IEC, and in New York under the direction of H. J. Wollner. Participation in the United Nations Standards Co-ordinating Committee is limited to those countries which are participating on a positive scale in the war effort of the United Nations. A number of proposals for international standardization work have been made, and the work of the committee can now be considered to be well under way. The committee was organized with the understanding that it would operate for only two years, leaving the form of future international organization to be determined later.

Technical Committees

COMMITTEE ON AIR TRANSPORTATION

The past year has been a period of major activity in the field of aircraft electric applications. A large number of technical papers were presented at three national meetings, and an extensive program has been undertaken in respect to aircraft electrical standards.

At the 1944 summer meeting in St. Louis, four of the technical sessions were devoted to aircraft subjects; a total of 17 papers were presented.

At the Pacific Coast technical meeting in Los Angeles, in August, aircraft electrical subjects and technical sessions occupied the dominant place. Fifteen of the technical sessions were concerned with aircraft problems, and 58 technical papers were presented and discussed.

At the winter technical meeting in New York, aircraft electrical problems occupied an important part of the program, and, in view of the restriction on the total number of papers and sessions which could be handled, there were two technical sessions at which nine papers were presented and one conference session covering the general problems of application of electric devices to military and commercial aircraft.

The committee met twice during the year on the occasions of the Los Angeles and New York technical meetings.

A "Report on Proposed Standard for Aircraft D-C Apparatus Voltage Ratings" was approved by the committee and recommended for publication for one year's trial use. This report has been in the process of preparation for the past two years, and, although some further revisions are probable, it is believed that adherence to the recommendations will result in improved operation of electric equipment in aircraft.

During the year, the committee has been in close contact with the SAE, NASC, NEMA, AAF, and the Navy Bureau of Aeronautics to assist in the formulation of appropriate technical standards. To carry out this work, four subcommittees were formed with assignments as follows:

1. *Aircraft Electric System Subcommittee.* To prepare an informative type of report on "Fundamental Characteristics of Aircraft Electric Systems." This subcommittee has made considerable progress in the preparation of a comprehensive outline and already has received from various sources some draft contributions.

2. *Aircraft Electric Control and Protective Devices Subcommittee.* To prepare electrical standards and test codes covering aircraft control and protective devices to aid in the rating, testing, and application or evaluation as such for aircraft service.

3. *Aircraft Wire and Cable Subcommittee.* The preparation of electrical standards and test codes covering the rating and testing and application of aircraft wires and cables.

4. *Aircraft Electric Rotating Machinery Subcommittee.* The preparation of electrical standards, tests, codes, and definitions for aircraft electrical rotating machinery. Immediate attention is being given by this subcommittee to the formulation of a suitable test code for aircraft d-c machines.

Consideration is being given to the formation of a subcommittee on brushes and brush test codes sponsored jointly by the committee on electric machinery and the committee on air transportation. It is believed that such a group can render worth-while service.

COMMITTEE ON AUTOMATIC STATIONS

The committee on automatic stations held two meetings during the year, one in Buffalo following the summer technical meeting, and one in New York during the winter technical meeting.

One of the principal matters discussed at these meetings concerned the revision of the "American Standard for Automatic Station Control, Supervisory and Telemetering Equipments, *C*37.2." The work of revising this Standard now has been completed, and it has been submitted to the AIEE Standards committee for approval.

The committee has sponsored papers on supervisory control and telemetering equipment and is continuing its efforts to bring before the Institute papers which will be of value to the engineering profession.

During the January meeting, plans were formulated for a conference session on automatic or supervisory control of high-voltage air switches and on automatic control of large capacitor banks. There appears to be considerable interest in these subjects, but on account of the present curtailment of travel it does not appear feasible to arrange this conference at the present time.

The committee is represented on several joint subcommittees and is participating in their work. The joint subcommittee on power system application of carrier current is undertaking several projects which should provide valuable information in this field. A report of the work of the sectional committee (*C*67) on preferred voltages under 100 was presented at the winter meeting of the committee on automatic stations by its representative and was given careful consideration. The committee on automatic stations also has appointed full representation on the joint subcommittee on telemetering. This subcommittee is working under the sponsorship of the committee on instruments and measurements.

COMMITTEE ON DOMESTIC AND COMMERCIAL APPLICATIONS

The committee has been enlarged to a total of 21 members, and two more subcommittees have been formed in addition to the three that were formed last year. Those formed this year are the subcommittee on laboratory projects, and the subcommittee on load characteristics. The other three subcommittees are on electrical hazards to farm animals, farm applications, and wiring.

The work of the two new subcommittees has been devoted since their inception entirely to organization, as practically all of the members have been too involved in vital war work to devote much time to committee activity.

The committee on domestic and commercial applications was formed just prior to the war with the purpose of propagating, more fully than had previously been done, the activities judged to be within its scope by the AIEE. It has been most unfortunate that the extreme pressure of war activities on the part of most of its members has precluded more vigorous pursuit of the domestic and commercial problems that confronted the committee. Excellent ground work has been laid, and conclusion of hostilities in the European theater of operation again will free some of the membership for committee work. At the conclusion of the war the committee should be in an excellent position to advance fully and rapidly with the original intent and purpose.

COMMITTEE ON ELECTRIC MACHINERY

Meetings of the main committee were held in June 1944 and January 1945, and one meeting of the subcommittee chairmen was held in October. The chairman attended the meetings of standards and technical-program committees during the year.

The committee has sponsored many sessions of interesting papers on the several technical programs and has held several conference sessions. Particular interest was shown this year in the subjects of temperature measurements and standards. Also, much interest was shown in the subject of machine insulation, particularly in the new silicone materials.

The synchronous-machine test code, which was passed on to the Standards committee, now has been approved and is ready for publication.

The questions of temperature measurements by thermocouple and by resistance were discussed at length in conference papers. The data on a-c machines were summarized in two papers, and it is hoped that this material soon can be presented to the Standards committee.

Similar data on d-c machines are being collected by the d-c subcommittee, but it is believed that further tests by interchanging machines between manufacturers is necessary before any conclusions can be drawn.

Several new items have come up for consideration by the d-c subcommittee, the problem of testing for stray-load loss, and the proposal that a test code for brushes be worked out jointly with the committee on air transportation.

The transformer subcommittee held two meetings during the year, one in Cleveland, Ohio, on October 27, 1944, and one in New York on January 23, 1945. The complete revision of the ASA "Guide for Operation of Transformers and Regulators C57.3" was completed and now is awaiting publication. It will be presented to the ASA sectional committee at the proper time. A revision of the data in ASA Standards, C57.1 and C57.2 on impulse testing has been practically completed. Several changes in the above ASA Standards were agreed to and passed on to the ASA sectional committee.

The co-ordinated study of life of transformer insulation is continued. Temperature gradients, hot-spot temperatures, and insulation strength of dry-type transformers are receiving consideration. A working group is considering the accuracy requirements for voltage-regulator control devices as well as operation of regulators above rating. The thermal capability of regulators on a reclosing cycle also is being studied.

The subcommittee on industrial control has sponsored a number of papers and has made a start on the study of standards for control devices.

COMMITTEE ON ELECTRIC WELDING

Two meetings of the committee were held, one in Cleveland, October 18, 1944, and one in New York, January 23, 1945. The discussions dealt with standards, particularly those concerning ASA Standards C52 on resistance-welding and arc-welding machines and the sponsoring and preparation of papers for technical sessions. The committee has assigned two of its members to assist with the preparation of arc-welding standards under the arc-welding subcommittee of C52, and has offered similar assistance for the resistance-welding subcommittee, as soon as active work is started by this subcommittee.

Two technical sessions were sponsored by the committee, one in St. Louis in June 1944, at which three technical papers and one conference paper were presented, and one in New York in January 1945, at which three technical papers and one conference paper were presented. The technical program in New York in January was confined to arc-welding subjects, and it was planned to sponsor a resistance-welding program for the 1945 summer technical meeting in Detroit. With the cancellation of that meeting, some of the original papers planned still will be written and presented as part of the technical-paper program, with discussions by mail, and others will be postponed until a later date.

COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY

Most of the work of the committee during the year was carried on by correspondence, small conference groups, and meetings of two very active subcommittees. Work of the committee has been limited during the war period. Details of new developments may be released later.

The subcommittee on voltage transients in arc-furnace circuits presented a paper on "Voltage Transients in Arc-Furnace Circuits" at the summer technical meeting in St. Louis. This was published as technical paper 44-99 and was read by the chairman of the subcommittee, J. E. Hobson. E. R. Whitehead became chairman in December 1944. At a meeting of the subcommittee held in Pittsburgh, Pa., on January 19, 1945, E. W. Boehne of the General Electric Company, gave a report and a very interesting discussion of his findings on overvoltages caused by circuit interruptions. F. J. Vogel of the Illinois Institute of Technology has been doing laboratory research on overvoltages in transformer secondary circuits, and he gave a report on the progress of this work. A survey of protective measures is in progress but was not advanced far enough at the time of the meeting to justify a report. An outline of desirable future action for the committee was drawn up.

The subcommittee on metallic rectifiers held two meetings, and reported considerable progress on a rectifier bibliography. It was expected that some time in April 1945 a preliminary draft would be collected, completed, and sent out to the membership. A list of proposed definitions for metallic rectifiers has been proposed. A full-day session wa
held with Army and Navy Air Corps an
Signal Corps officers in discussing speci
tests for rectifiers suitably protected for u
in high humidity. Considerable progre
has been made, and a series of co-operati
tests at various plants are being undertak
to establish standard methods of tests as w
as means of finding approved methods
protection. Some of the government pr
curement specifications will be incorporat
in the new standards when they are drafte

The committee is represented on the ne
joint subcommittee on induction and
electric heating.

COMMITTEE ON ELECTRONICS

The committee has been active in solic
ing and promoting papers on electronic su
jects. Both the winter technical meeting a
Electrical Engineering had a satisfactory p
centage of such papers.

This year at the winter technical meeti
as an experiment, the available papers on t
subject of electronics were distributed
other committees whose sessions covered t
subjects involved. This was done to increa
the number of papers on electronics p
sented to the membership.

As an activity of the joint subcommitt
on induction and dielectric heating, the co
mittee on electronics took an active part
organizing and conducting an informal te
nical conference on the subject of dielect
heating. This was well attended, whi
indicated that such conferences form a u
ful medium of promoting various aspects
electronics among the members of the
stitute.

Two subcommittees of the committee ha
been active during the year. A worki
group of the subcommittee on electro
standards has had a number of meetings a
is making excellent progress on the mat
of nomenclature, and letter and graphi
symbols. The object here has been to
fine electronic devices, particularly th
outside of the radio field.

The subcommittee on mercury-arc re
fiers has been renamed the power electron
subcommittee, and has been engaged activ
in the preparation of standards for mercu
arc power converters. The standards
cover definitions (rectifier names and let
symbols), standards (ratings and bases
acceptance tests), test code, operating gu
and standards for rectifier transformer. T
subcommittee also has organized a work
group to prepare a report on "Induct
Co-ordination of Rectifier Equipment."

The scope of technical papers that can
obtained at the present time is restricted
cause of the war program, but it is belie
that a sufficient number can be made av
able to keep this subject active and well rep
sented at possible future technical meeti
and in the pages of *Electrical Engineering*
the *Transactions*.

COMMITTEE ON INDUSTRIAL POWER APPLICATIONS

The main project of the committee
the completion of the report on "Elec
Power Distribution for Industrial Plan
The report was presented at one of the te
nical sessions at the 1944 summer techn
meeting in St. Louis, and was approved
publication by the board of directors.
first issue of 10,000 copies was printed
released in January 1945. It already

been sold out completely, and a second printing of 10,000 copies since has been approved. Plans are being developed for the translation of the report into Spanish and Portuguese by the International General Electric Company and Westinghouse Electric International Company for distribution by these companies in Central and South America.

This report is in the form of a manual of 100 printed pages, 8 by 11 inches in size, in flexible binding. It contains in condensed form the basic information needed by an electrical engineer or industrial architect to design an industrial power-distribution system. It is neither a code, nor a standard but is intended to promote the use of sound engineering principles in the design of such a system and the selection of equipment for it.

A subcommittee has been appointed to assemble and edit suggestions for revisions of the report, in preparation for a future second edition.

At the 1944 summer technical meeting, the committee sponsored, jointly with the committee on electronics and the committee on power transmission and distribution, a technical session for the presentation of five related papers on the use and design of electronic power converters. Another session was devoted to the presentation of two papers on the control and switching of shunt capacitors, a conference paper discussing electrical facilities of an important war plant, and a discussion of the afore-mentioned committee report.

An organization meeting was held of members of the newly created subcommittee on inductive and dielectric heating and members of the sponsoring committees, the committees on electronics, electrochemistry and electrometallurgy, and industrial power applications. J. J. Orr, chairman of this subcommittee, has surrounded himself with a highly representative group of men, all interested and active in the developments in high-frequency heating.

At the 1945 winter technical meeting in New York, the committee sponsored the presentation of eight technical papers in two technical sessions, and a conference session devoted to a discussion of industrial system and apparatus voltage ratings. Speakers represented the utilities, electric-machinery manufacturers, and the industrial power user. The conference was well attended and developed a great deal of interest.

Another conference session was sponsored by the subcommittee on inductive and dielectric heating. This session too was very well attended, confirming the great interest of electrical engineers in developments in this modern field. The very fine start made by the new subcommittee gives promise of fine practical achievements in coming years in a field which is so new that few, if any, standards have yet been developed.

A luncheon meeting of members of the main committee was used to lay plans for the coming year. The increasing importance of co-ordinated drives in industrial processes is recognized by the committee, and special efforts will be made to stimulate the presentation of papers dealing with such installations.

COMMITTEE ON INSTRUMENTS AND MEASUREMENTS

In spite of the restrictions of the war, which prevent the publication of many potential papers, the number of papers approved by the committee for the winter technical meeting was greater than could be accommodated on the program. Also, although handicapped by duties imposed by the war, the members of the committee have advanced many projects, particularly those in the fields of definitions and standards.

At the summer technical meeting two papers sponsored by the committee were presented, one on a method of measuring dielectric properties at ultrahigh frequencies and the other on high-frequency cable design and testing. At a session of the winter technical meeting, four papers in widely diverse fields were presented, one on a method of improving bushing current transformers by superposing third-harmonic frequency excitation on the core, one on a modulated high-frequency-system method of telemetering developed for the City of Seattle, Wash., one on the dynamic measurements of electromagnetic devices such as subrelays, and the fourth on a compact portable instrument for measuring insulation resistance in the field with direct current at high voltage. A fifth paper sponsored by the committee on an electronic interval timer for arc duration was presented at the session on industrial control.

The committee is finding that the employment of electronic circuits and devices for making measurements is increasing rapidly, and several of the new members appointed to the committee in the past year were selected because of their proficiency in the electronic field.

The subcommittees have been active, particularly in making several additions and changes in the definitions of electrical terms in preparation for some future revision of the present "American Standard Definitions of Electrical Terms" and in bringing into agreement the definitions relating to watthour meters in that volume, the "Meterman's Handbook," and the "Code for Electricity Meters." A former report on a proposed Standard 40 for recording instruments is being brought to the status of a standard, and a draft is being circulated for review among Institute members and others who have interest in such a standard. Considerable progress has been made in the preparation of the master test codes for both resistance and temperature measurements. The subcommittee on ultrahigh-frequency measurements has in preparation an article for *Electrical Engineering* on recent developments in measurements in the ultrahigh-frequency field. The subcommittee on dielectric measurements in the field has compiled a bibliography on the subject and now is preparing a report on the methods now available for such measurements together with their scope.

For some time past there has been no permanent committee or subcommittee in the Institute to which matters concerning instrument transformers could be readily referred. Hence, during the past year, the committee on instruments and measurements has established a permanent subcommittee on instrument transformers, on which are representatives of widely diversified interests. The formation of this subcommittee was facilitated by the close co-operation of the AIEE committee on protective devices and the ASA subcommittee on instrument transformers. In view of the rapid expansion of the field of industrial control the name and the scope of the subcommittee on that subject have been changed to subcommittee on electrical servomechanisms and follow-up devices. Also, if a new committee on industrial control devices is authorized by the Institute, the committee on instruments and measurements desires representation thereon, since a large number of industrial control devices depend on measuring devices to initiate their operation.

In accordance with a request from the National Roster of Scientific and Specialized Personnel of the War Manpower Commission, the committee has submitted to it a statement of the duties, skills, and functions of those engaged in the instrument and measurement field.

The committee also has been requested to co-operate with the Sections committee in the formation of technical groups on instruments and measurements in the different Sections, through the activity of committee members in their own Sections and by assisting in supplying speakers on subjects in the instrument and measurement field. The committee already has taken action through letters and other material sent to its members and by making available to Section chairmen the names of members of the committee in their Section. In the Boston Section such a technical group is already in active operation.

COMMITTEE ON LAND TRANSPORTATION

A joint meeting of the committee on land transportation and the oil and gas power group of the railroad division of the American Society of Mechanical Engineers was held on November 29, 1944, in New York. Papers were presented at this meeting on the subject of gas-turbine locomotives, covering developments in Switzerland and in the United States and the present status and prospects for future developments of the gas turbine as a propulsion unit for road locomotives. The meeting was very well attended, and interest in the subject was pronounced.

On the morning of January 25, 1945, during the winter technical meeting in New York, a meeting of the committee was held to discuss various subjects to be brought before the committee members. The technical papers already available were reviewed, and additional papers to be obtained on subjects of interest and value along lines covered by this committee were discussed. In the afternoon the committee sponsored a technical session at which the four papers presented were received with a great amount of interest, and extensive discussion resulted.

Three technical papers have been made available for use in the spring technical-paper program.

In the interest of keeping travel to a minimum under present transportation conditions, no additional committee meetings have been scheduled.

COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT

No technical sessions or conferences were sponsored by the committee during the year, and a conference tentatively planned for the summer meeting has been abandoned with the cancellation of this meeting.

A meeting of the committee was held at Institute headquarters on January 23, 1945, with a substantial number of the members in attendance.

The report of the subcommittee on preferred characteristics of electric power for lighting has been prepared, and, in accordance with recommendation made at the January committee meeting, will be referred to other interested technical committees for comments and suggestions.

COMMITTEE ON MARINE TRANSPORTATION

During the year, four new members were added to the committee. All of these new members are associated with prominent organizations, and their time is occupied completely with marine electrical matters. They are very helpful to the committee, and their enthusiasm has aided in a more critical review of the existing standard.

The committee had one all-day meeting, and four two-day meetings. The attendance at all the meetings has been excellent, despite the fact that all the members are overloaded with war work.

In accordance with the custom of the committee, the 93 pages of the 1940 edition of Standard 45 have been subdivided into eight sections and assigned to an equal number of subcommittees. These subcommittees have reviewed critically the 1940 edition and reported their findings to the committee. This has been a very laborious and time-consuming task, for the rapid development of marine electric installations during this quantity production of ships and increased uses of electric power, including electronic devices, has necessitated many revisions to keep abreast of the changing conditions. In addition these revisions have been necessitated by the greatly increased use of a-c distribution systems through the ship and the increased number of electrically propelled vessels.

COMMITTEE ON POWER GENERATION

The two major projects of the committee have been practically completed. The joint subcommittee with ASME has prepared a specification for steam-turbine governors, which has been issued on a trial basis. This work is being extended to other kinds of prime movers.

Another project in which the committee on power generation has participated actively was the preparation of standards for 3,600-rpm steam-turbine generators for sizes 10,000–60,000 kw. This work is virtually completed, and it is expected that the recommended specification will be issued on a trial basis this year.

The technical sessions sponsored by the committee during the summer technical meeting in St. Louis and the winter technical meeting in New York were devoted to diverse subjects of interest to the committee and general membership of the Institute.

A well-attended and quite successful technical conference was held at the last winter meeting on the subject of central-station auxiliaries.

The plans of the committee for the immediate future include a symposium on hydroelectric systems, a series of papers on excitation systems, in addition to further contributions on the subject of central-station auxiliaries.

COMMITTEE ON POWER TRANSMISSION AND DISTRIBUTION

A meeting of the subcommittee chairmen was held in October 1944, and a full meeting of the committee was held at the winter technical meeting in New York in January 1945.

Technical Meetings. At the summer meeting in St. Louis in June 1944, the committee sponsored two technical sessions. One session dealt with general transmission and distribution problems, and the other with cables. At the winter meeting in New York in January 1945, the committee sponsored three technical sessions, and one conference session. The technical sessions dealt with lightning and protective relaying, supervisory control and stability, and cables. The conference was on the subject of wartime practices on distribution systems, and consisted of four conference papers and discussion.

Subcommittee Activities. The distribution subcommittee and stations subcommittee devoted their principal activities to arrangements for the conference session, which was sponsored jointly by the two subcommittees.

The general systems subcommittee is planning a conference session on the factors involved in serving kilowatt and kilovar and the effect on the rate structure.

The transmission subcommittee through its working group on towers, poles, and conductors is sponsoring papers dealing with modern trends in wood-pole structure design. The working group on cables is arranging papers on cable temperatures and also is planning a review of duct heating constants. The working group on lightning and insulators is collecting material for an addition to the lightning reference book covering the period 1934 to 1944. Work also is proceeding on a report on predicting lightning performance of transmission lines. During the year, "AIEE Standard 41, Insulator Tests," sponsored by this group was published as "ASA Standard *C*29.1."

COMMITTEE ON PROTECTIVE DEVICES

One meeting of the executive committee was held in the fall, at which time all of the subcommittees were organized and the work outlined for the year. One meeting of the full committee was held in January to review progress reports by the subcommittees and to get suggestions from all members about the future program.

The committee sponsored ten technical papers at the 1944 summer meeting, four at the Pacific Coast meeting and 11 at the winter meeting. Plans are being made to continue the preparation of technical papers, particularly those having an important bearing on wartime developments or practices.

Activities of the subcommittees may be summarized as follows:

Circuit Breaders, Switches, and Fuses. Standard 25, covering fuses above 600 volts, was approved and sent to the Standards committee with the recommendation that it should be published as an approved standard.

Standard 20, covering low-voltage air circuit breakers, has been worked on diligently through the year. The wide interest and broad field of use of this apparatus has encouraged much discussion of the material in the proposed revision.

A draft of a Standard on "Reclosing Devices for Distribution Circuits" has been completed by the working group.

On Standard 22, "Air Switches," no active work is being done. A working group is collecting data and comments that may lead to suggesting revisions.

Standard 27, "Switchgear Assemblies," was reviewed by a working group, which reported that "the standards as issued in August 1942 do not require any action looking toward revision at this time."

There has been no activity looking toward a revision on Standard 19, "Power Circuit Breakers."

Items recommended for continuing by future committees are:

(*a*). Study of the calculating of short-circuit currents for low-voltage circuits.

(*b*). Revision of methods used for rating power circuit breakers.

(*c*). Derating factors for air circuit breakers on reclosing service.

Some engineers feel that air circuit breakers need not be derated as severely as oil circuit breakers when used on reclosing service.

Lightning-Protective Devices. The eighth draft of the proposed AIEE Standard for expulsion-type distribution arresters was sent to members of the subcommittee for final approval March 2, 1945.

Two of the projects, namely, industry performance characteristics of high-voltage protector tubes and rod-gap characteristics have been delayed until a suitable industry standard for impulse testing has been set up.

A survey was started in co-operation with the committee on electric machinery to determine the success of present methods used for lightning protection of rotating a-c machines, covering both protected and unprotected machines.

The performance data of expulsion-type distribution arresters are being secured from all manufacturers and will be published as a committee report giving the range of performance values available.

Fault-Current-Limiting Devices. The working group revising Standard 32 for "Neutral Grounding Devices" has been very active, but much still remains to be done.

The working group on "Present-Day Grounding Practices" is well organized to prepare a report of interest and value in connection with postwar conversions and new construction. Steps have been taken to enlist the aid and support of other technical committees interested.

Relays. This working group has prepared a bibliography for the preceding year and has distributed this to members of the relay subcommittee. This is a continuing program and is of considerable value in keeping all interested members up to date.

Generator Protection. This working group has been studying various phases of the subject and conducted a conference session at the winter technical meeting. It is expected the working group ultimately will prepare a report on recommended practices.

Current Transformers. A working group is preparing a report on the use of current transformers having a secondary current rating of less than five amperes which will indicate where these can be used to advantage and will include a discussion of application and limitations.

Protection of Powerhouse Auxiliaries. A working group is preparing a questionnaire for limited circulation prior to issuing a report on present practices.

Transformer Protection. A working group was organized during the year to study various American and foreign practices and to prepare a report.

Instrument Transformer Standards for Relays. At the request of the ASA committee on transformers, a draft of a report has been completed recommending material for a proposed ASA section on instrument transformers.

National Electrical Code. A small working group has been working closely in co-operation with the committee on revision of the "National Electrical Code," and has made a number of recommendations, some of which have been adopted. This activity has been terminated.

Distribution Circuit Protection. A working group has just been organized to study the effect of distribution-circuit construction on the protection that can be obtained.

COMMITTEE ON APPLICATIONS OF ELECTRICITY TO THERAPEUTICS

The committee held no meetings during the year, as all of the members are engaged in war work. The members have, however, corresponded.

The war has resulted in the development of much new equipment which should prove valuable in the field of electrical therapy. Among the new developments are apparatus for determining the relaxation of muscles, for the production of very high-voltage cathode rays and for X rays at new wave lengths. Equipment is available for producing X rays at any voltage up to 100,000,000. This new equipment will be available for experimental therapy following the cessation of hostilities. There is evidence that the new rays may be of value in treating certain diseases.

It is the expectation of the committee that there will be a considerable and important development in the field of electrical therapeutics following the war.

Awards

COMMITTEE ON AWARD OF INSTITUTE PRIZES

Four Institute prizes and seven District prizes were awarded for papers presented during the calendar year 1943. As explained previously, the decrease in the number of District prize awards from that reported several years earlier is due to the effect of the training programs in the various colleges. No District prize for Branch paper was awarded during the academic year ending June 30, 1944.

A number of the technical papers were of a high order, and a choice between leading papers worthy of award was very close in several of the classifications. Two honorable mentions were made in the class of best paper prize and one honorable mention in the class of initial paper prize. The committee gratefully acknowledges the aid received from the technical committees and their reviewers in nominating and grading the large number of papers considered for the awards.

EDISON MEDAL

The Edison Medal, awarded by a committee composed of 24 members of the Institute, was presented for 1944 to E. F. W. Alexanderson, consulting engineer, General Electric Company, Schenectady "for his outstanding inventions and developments in the radio, transportation, marine, and power fields." The presentation took place January 24, 1945, during the winter technical meeting. The medal may be awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

LAMME MEDAL

The Lamme Medal committee awarded the medal for 1944 to S. H. Mortensen, chief electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., "for his pioneer work in the development of self-starting synchronous motors and for his contributions to the development of large hydraulic and steam-turbine-driven generators." Arrangements are being made for the presentation of the medal at the annual business meeting in New York, June 27, 1945. The medal may be awarded annually to a member of the AIEE "who has shown meritorious achievement in the development of electric apparatus or machinery."

JOHN FRITZ MEDAL

The John Fritz Medal board of award, composed of representatives of the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, ASME, and AIEE, awarded the 40th medal, for 1944, to John L. Savage, consulting engineer, for his "superlative public service in conceiving and administering the engineering of mammoth dams, both in America and beyond the seven seas."

HOOVER MEDAL

The Hoover Medal was established through a trust fund created by a gift from Conrad N. Lauer and is to be awarded periodically "to a fellow engineer for distinguished public service" by a board representing the ASCE, AIME, ASME, and AIEE. The seventh medal, for 1944, was awarded to Ralph E. Flanders, president, Jones and Lamson Machine Company, Springfield, Vt.

ALFRED NOBLE PRIZE

This prize, established in 1929, consists of a certificate and a cash award from the income of a fund contributed by engineers and others to perpetuate the name and achievements of Alfred Noble, past president of the ASCE, and of the Western Society of Engineers. It may be made to a member of any of the co-operating societies, ASCE, AIME, ASME, AIEE, or WSE, for a technical paper of particular merit accepted by the publication committee of any of these societies, provided the author, at the time of such acceptance, is not over 30 years of age. The award for 1944 was presented to W. R. Wilson, General Electric Company, Pittsfield, Mass., for his paper "Corona in Aircraft Electric Systems as a Function of Altitude."

CHARLES LE GEYT FORTESCUE FELLOWSHIP COMMITTEE

A fellowship amounting to $400 was awarded to Morton M. Astrahan, a student of Northwestern University and a veteran of the present war. Mr. Astrahan will undertake graduate work in the field of electronics at the California Institute of Technology starting in the fall of this year. The award is to cover expenses for the second semester as Mr. Astrahan will receive aid from the Veterans' Administration for the first semester.

Joint Activities

UNITED ENGINEERING TRUSTEES, INC.

This organization manages property and funds held jointly by the four founder societies, including the Engineering Societies Building, the Engineering Societies Library, and the endowment funds of the Engineering Foundation.

The building is fully occupied by engineering organizations, and additional space is needed both for offices and for meetings. Therefore, there has been a renewal of planning for the future adequate housing for engineering societies, and various types of projects are under serious consideration.

Increased revenue from meeting halls and the reduction of interest paid to the societies to token payments produced a small credit balance for the year ended September 30, 1944.

An abstract of the annual report for the year ended September 30, 1944, appeared in *Electrical Engineering* for February 1945, page 82.

ENGINEERING FOUNDATION

The Engineering Foundation was established in 1914 as a joint organization of the four societies, ASCE, AIME, ASME, and AIEE, for "the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering and the good of mankind."

Each research project supported by it is under the sponsorship of one of the founder societies.

During the year 1944–45, work on five projects has been continued, and three new projects were initiated. The small number of each reflects the lessened demand for Foundation support caused by extensive government support of all types of research of probable importance to the war effort and the withdrawal of research personnel from the educational institutions to serve in war activities.

The Welding Research Council sponsored jointly by the AIEE and the American Welding Society has been in operation eight years. Its work is carried on by eight research committees. The principal accomplishment during the year 1943–44 was the development of a better understanding of the fundamentals of weldability and weld stresses.

An abstract of the annual report for the year ended September 30, 1944, appeared in *Electrical Engineering* for February 1945 pages 82–4.

ENGINEERING SOCIETIES LIBRARY

The Engineering Societies Library was formed by combining the separate libraries of the ASCE, AIME, ASME, AIEE, and preparing a composite card catalogue.

Special services rendered by the library include: photoprints, searches, abstracts, translations, bibliographies, book loans by mail.

Wartime conditions have prevented the usual growth in the book collection and greatly increased the demand for photostat prints and for other services.

An abstract of the annual report for the year ended September 30, 1944, appeared in *Electrical Engineering* (Feb '45, p 84–5).

EMPLOYMENT SERVICE

Operating as an incorporated nonprofit organization, the Engineering Societies Personnel Service, Inc., assists members of the Founder Societies desiring to secure new positions and employers searching for engineers. Nonmembers may receive such assistance when positions available cannot be filled by members.

Offices are operated in New York; Boston, Mass.; Detroit, Mich.; Chicago; and San Francisco, Calif.; with the co-operation of the Engineering Societies of New England in Boston, the Engineering Society of Detroit in that city, the Western Society of Engineers in Chicago, and the Engineers Club of San Francisco in that city.

For several years, the service has been on a self-supporting basis, but the prevailing scarcity of engineers available for new positions has reduced the number of placements. A record of registration and placements during the past year is given in Table X.

Table X. Analysis of Employment Service

	Men Registered						Men Placed					
Month	New York	Chicago	San Francisco	Detroit	Boston	Total	New York	Chicago	San Francisco	Detroit	Boston	Total
1944												
May	88	17	64	21	18	208	23	9	25	7	8	72
June	95	25	73	24	11	228	31	12	18	5	7	73
July	69	26	54	17	14	180	21	8	18	4	6	57
August	95	29	69	23	13	229	20	9	24	4	6	63
September	89	30	59	22	10	210	25	6	27	9	4	71
October	73	30	65	19	11	198	30	3	16	9	6	64
November	77	24	65	23	17	206	25	13	23	11	3	75
December	75	14	55	16	5	165	18	5	18	4	7	52
1945												
January	71	12	65	10	2	69	21	6	15	4	3	49
February	61	28	35	11	10	145	21	14	15	5	3	58
March	76	27	49	25	9	186	26	6	20	9	2	63
April	84	23	47	20	8	182	22	11	18	6	4	61
Total	953	285	696	231	128	2206	283	102	237	77	59	758

ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT

This council, organized in 1932 to engage in activities leading toward the enhancement of the professional status of the engineer, includes three representatives of each of the eight participating organizations, which are the ASCE, AIEE, ASME, and AIME, the SPEE, the National Council of State Boards of Engineering Examiners, and the Engineering Institute of Canada. Its principal activities have been carried on by four committees: student selection and guidance, engineering schools, professional training, and professional recognition.

One of the principal accomplishments during the year which ended on September 30, 1944, was the development of a plan for accrediting technical Institutes. This will be administered by a subcommittee of the committee on engineering schools which has administered the accrediting of engineering college curricula.

A revised general reading list for junior engineers was approved, progress was made in the preparation of a manual for junior engineers, and continuing progress was reported in the measurement and guidance program.

Although, due to wartime programs, few inspections of engineering curriculums have been made, plans are being made for the reappraisal of all curriculums after the war.

A comprehensive report on the activities during the year ended September 30, 1944, was published in *Electrical Engineering* for December 1944, pages 452–4.

JOINT CONFERENCE COMMITTEE

This committee, composed of the presidents, immediate past presidents, and secretaries of the Founder Societies and the American Institute of Chemical Engineers, considered topics of interest to the societies.

The committee serves in an advisory capacity, making occasional recommendations to the societies on matters of interest to all.

RADIO TECHNICAL PLANNING BOARD

This joint advisory body, organized in 1943, will formulate recommendations on the technical future of radio developments for submission to the Government, industry, and the public.

Initial member bodies in addition to the AIEE are: Radio Manufacturers Association; Institute of Radio Engineers; American Institute of Physics; American Radio Relay League; F M Broadcasters, Inc.; International Association of Chiefs of Police; National Association of Broadcasters; and National Independent Broadcasters. The board includes one representative of each member organization.

The work is carried on mainly by 13 technical panels, which have prepared many comprehensive reports.

REPRESENTATIVES

A complete list of the more than 30 joint activities in which the Institute is represented appears in the Year Book and in the September issue of *Electrical Engineering* each year.

Appreciation

With grateful recognition of the extent and effectiveness of the activities and the large increase in membership during the past year, the board of directors expresses its deep appreciation and thanks to the national committees, and the District, Section, and Branch officers for their generous contributions of energy and time, despite the adverse conditions, and to the members in general for their continuing interest and participation in Institute affairs.

Respectfully submitted for the board of directors.

H. H. HENLINE

May 29, 1945 *National Secretary*

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS

1 EAST 44TH STREET
NEW YORK

May 18, 1945

American Institute of Electrical Engineers,
33 West 39th Street, New York.

Dear Sirs:

We have examined the balance sheet of the American Institute of Electrical Engineers, and schedule of securities owned, as of April 30, 1945, and the related statements of cash receipts and disbursements of operating and restricted funds for the year ended that date, have reviewed the accounting procedures of the Institute, and have examined its accounting records and other evidence in support of such financial statements. Our examination was made in accordance with generally accepted auditing standards applicable in the circumstances and included all auditing procedures we considered necessary, which procedures were applied by tests to the extent we deemed appropriate in view of the system of internal control.

In our opinion, the accompanying balance sheet, schedule of securities owned, and statements of cash receipts and disbursements fairly present, respectively, the financial condition of, and securities owned by, the Institute as of April 30, 1945, and its recorded cash receipts and cash disbursements for the year ended that date, in conformity with generally accepted accounting principles and practices applied on a basis consistent with that of the preceding year.

Yours truly,

(*Signed*) HASKINS & SELLS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

(Incorporated in New York)

Balance Sheet, April 30, 1945

Exhibit A

ASSETS		
Property Fund Assets:		
One-fourth interest in physical properties of United Engineering Trustees, Inc.:		
Land, buildings, and equipment (less depreciation and renewal reserve)	$369,974.15	
Funded depreciation and renewal reserve	128,474.33	
Total	$498,448.48	
Equipment:		
Library—volumes and fixtures—estimated value	36,366.37	
Office furniture and fixtures (less reserve for depreciation, $26,047.47)	11,395.49	
Works of art, etc.	3,001.35	
Cash—proceeds from redemption of mortgage certificate	612.91	
Total property fund assets		$ 549,824.60
Restricted Fund Assets:		
Securities—at cost, less reserve, $7,372.65 (quoted market value, $398,266.61)—Schedule 1	$359,259.96	
Cash (Exhibit C)	35,064.88	
Accrued interest receivable	89.75	
Total restricted fund assets		394,414.59
Operating Fund Assets:		
Cash (not including $1,295.18 for Federal taxes withheld from employees) (Exhibit B)	$ 77,206.09	
Accounts receivable:		
Members—for dues (less reserve, $5,700.00)	6,114.11	
Advertisers	6,729.00	
Miscellaneous	3,544.12	
Accrued interest receivable	4,309.52	
Inventories:		
Transactions, etc.	1,048.50	
Electrical Definitions	4,388.40	
Work in process (May issue of *Electrical Engineering*, etc.)	7,706.26	
Text and cover paper	6,799.68	
Badges	1,589.34	
Total operating fund assets		119,435.02
Total		$1,063,674.21

LIABILITIES		
Property Fund Reserve		$ 549,824.60
Restricted Fund Reserves:		
Reserve Capital fund	$371,392.58	
Life Membership fund	8,427.63	
Member for Life fund	3,268.71	
International Electrical Congress of St. Louis Library fund	5,748.05	
Lamme Medal fund	4,456.66	
Mailloux fund	1,120.96	
Total restricted fund reserves		394,414.59
Operating Fund Reserves, Liabilities, Etc.:		
Accounts payable	$ 22,485.83	
Deferred income:		
Dues received in advance	3,200.10	
Entrance fees and dues advanced by applicants for memberships	1,136.68	
Subscriptions to publications received in advance	13,771.06	
Miscellaneous (including unallocated receipts)	967.25	
Operating fund reserves	77,874.10	
Total operating fund reserves, liabilities, etc.		119,435.02
Total		$1,063,674.21

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Cash Receipts and Disbursements of Operating Fund for the Year Ended April 30, 1945

Exhibit B

Cash on Deposit With The National City Bank of New York, May 1, 1944 (not including $1,079.42 for Federal taxes withheld from employees)		$ 53,749.13
Receipts:		
Dues (including $113,688.00 allocated to *Electrical Engineering* subscriptions)	$247,017.36	
Advertising	108,173.90	
Transactions subscriptions	7,832.37	
Electrical Engineering subscriptions	19,825.13	
"Electrical Definitions"	935.25	
"Electric-Power Distribution for Industrial Plants"	7,803.80	
Miscellaneous publications (preprints, Standards, *Electrical Engineering* supplement, etc.)	25,299.78	
Students' fees	10,848.85	
Entrance fees	17,159.03	
Membership badges	4,088.06	
Transfer fees	2,908.00	
Interest and dividends on investments of Restricted Capital fund	10,037.77	
Miscellaneous	178.63	
Total receipts		462,107.93
Total		$515,857.06
Disbursements:		
Publication expense:		
Electrical Engineering	$112,263.90	
Transactions	10,154.47	
Year Book	4,682.86	
Miscellaneous publications (preprints, Standards, "Industrial Plants" report, *Electrical Engineering* supplement, etc.)	27,156.68	
Institute meetings	16,159.00	
Institute Sections	48,358.49	
Institute Branches	2,748.23	
Finance committee	629.29	
Headquarters committee	184.09	
Membership committee	9,059.91	
Standards committee	11,365.60	
Forward	$242,762.52	$515,857.06
Total (forward)		$515,857.06
Disbursements (forward)	$242,762.52	
Technical committees	838.20	
Retirement system AIEE—normal contribution (see Exhibit C for payment of $25,000.00, special contribution from Reserve Capital fund)	5,074.35	
Radio Technical Planning Board	1,000.00	
Traveling expenses:		
Geographical Districts:		
Executive committees	4,731.57	
Vice-presidents	793.92	
Branch counselors and chairmen	2,045.97	
President's appropriation	1,245.09	
AIEE representatives	176.92	
Board of directors	5,655.16	
National nominating committee	1,138.68	
Administrative expenses	58,302.06	
Geographical Districts—Branch paper prizes	353.29	
Institute prizes, national	409.00	
American Co-ordinating Committee on Corrosion	25.00	
American Standards Association	1,500.00	
United Engineering Trustees, Inc.:		
Building assessment	17,813.56	
Library assessment	11,006.20	
Engineers' Council for Professional Development	1,700.00	
Engineering Foundation Project—welding research	250.00	
National Committee State Board Engineering Examiners	350.00	
International Committee on Illumination	30.00	
John Fritz Medal	50.00	
National Fire Protection Association—Dues	60.00	
Membership badges	4,585.47	
Legal services	250.00	
Committee on collective bargaining and related matters	691.40	
Office furniture and fixtures, and repairs	5,313.33	
Edison Medal committee	230.57	
Transfers:		
To Reserve Capital fund	67,000.00	
To Member for Life fund	3,268.71	
Total disbursements		438,650.97
Cash on Deposit With The National City Bank of New York, April 30, 1945 (not including $1,295.18 for Federal taxes withheld from employees)		$ 77,206.09

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Cash Receipts and Disbursements of Restricted Funds for the Year Ended April 30, 1946

Exhibit C

	Restricted Funds						
	Reserve Capital Fund	Member for Life Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total Restricted Funds
Cash on Deposit With The National City Bank of New York and Various Savings Banks, May 1, 1944	$ 27,676.29		$2,827.14	$401.80		$1,104.34	$ 32,009.57
Receipts:							
Interest on bonds			$ 125.00	$130.00	$ 240.00		$ 495.00
Interest on bank balances			43.56			$ 16.62	60.18
Proceeds from sale of securities	$ 8,535.00				4,200.00		12,735.00
Transfer from operating fund	67,000.00	$3,268.71					70,268.71
Life membership fees			845.66				845.66
Total receipts	$ 75,535.00	$3,268.71	$1,014.22	$130.00	$4,440.00	$ 16.62	$ 84,404.55
Total	$103,211.29	$3,268.71	$3,841.36	$531.80	$4,440.00	$1,120.96	$116,414.1[illegible]
Disbursements:							
Purchase of securities	$ 51,624.89				$4,253.78		$ 55,878.67
Retirement system AIEE—contribution to meet the requirements of an increase in the allowance for prior services of the headquarters staff	25,000.00						25,000.00
Transfer to operating fund			$ 460.57				460.57
Engrossing certificate					10.00		10.00
Total disbursements	$ 76,624.89		$ 460.57		$4,263.78		$ 81,349.24
Balance on Deposit With The National City Bank of New York and Various Savings Banks, April 30, 1945	$ 26,586.40	$3,268.71	$3,380.79	$531.80	$ 176.22	$1,120.96	$ 35,064.88

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Securities Owned, April 30, 1945

Schedule 1

	Principal Amount of Bonds or Number of Shares of Stock	Reserve Capital Fund	Restricted Funds			
			Life Membership Fund	International Electrical Congress Library Fund	Lamme Medal Fund	Total Restricted Funds
Railroad Bonds:						
Atlantic Coast Line, First Consolidated 4%, due 1952	$ 4,000.00				$4,253.78	$ 4,253.78
Baltimore & Ohio, Pittsburgh, Lake Erie & West Virginia System 4%, due 1951	10,000.00	$ 6,450.00				6,450.00
Chicago & Erie Railroad Company 5% first mortgage, due 1982. Registered	1,000.00	1,105.00				1,105.00
New York Central Railroad Company 4% series A consolidated mortgage, due 1998	10,000.00	6,100.00				6,100.00
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950 (certificates of deposit). Registered, Stamped	6,000.00*	5,497.50*				5,497.50*
Total railroad bonds		$ 19,152.50			$4,253.78	$ 23,406.28
Public Utility Bonds:						
New York & Queens Electric Light & Power Company $3^1/_2$% first and consolidated mortgage, due 1965	10,000.00	$ 11,000.00				$ 11,000.00
United States Government Bonds:						
Treasury Savings bonds series D, due July 1, 1949	10,000.00	$ 7,644.00				$ 7,644.00
Treasury Savings bonds series D, due January 1, 1950	10,000.00	7,500.00				7,500.00
Treasury bonds 2%, due 1950/48	77,000.00	78,130.94				78,130.94
Treasury bonds 2%, due 1950, Registered	3,000.00	3,060.94				3,060.94
Treasury bonds $2^1/_2$%, due 1968/63	20,000.00	15,000.00	$5,000.00			20,000.00
Treasury bonds $2^1/_2$%, due 1972/67	6,300.00	1,100.00		$5,200.00		6,300.00
Treasury bonds, $2^1/_2$%, due 1972, Registered	3,500.00	3,516.41				3,516.41
Defense bonds series F, due June 1, 1953	34,000.00	25,160.00				25,160.00
Defense bonds series G, $2^1/_2$%, due December 1, 1954	18,000.00	18,000.00				18,000.00
War Savings Bonds series G, $2^1/_2$%, due September 1, 1955	40,000.00	40,000.00				40,000.00
War Savings Bonds series G, $2^1/_2$%, due 1956	17,000.00	17,000.00				17,000.00
Total United States Government bonds		$216,112.29	$5,000.00	$5,200.00		$226,312.29
Capital Stocks:						
American Can Company	60 shares	$ 4,988.40				$ 4,988.40
American Telephone & Telegraph Company	50 shares	8,183.65				8,183.65
Atchison, Topeka & Santa Fe Ry. Company—Preferred	150 shares	13,035.46				13,035.46
Boston Edison Company	200 shares	4,927.50				4,927.50
Commonwealth Edison Company	200 shares	7,580.68				7,580.68
Consolidated Natural Gas Company	11 shares	221.92				221.92
Eastman Kodak Company	35 shares	4,768.23				4,768.23
E. I. du Pont de Nemours & Company	50 shares	7,982.07				7,982.07
General Electric Company	130 shares	4,463.80				4,463.80
General Motors Corporation	100 shares	4,235.53				4,235.53
International Harvester Company	100 shares	5,030.50				5,030.50
International Match Realization Co., Ltd. voting trust certificates for capital shares of International Match Corporation	6 shares*	1,875.15*				1,875.15*
Ohio Edison Co. 4.40% preferred stock	150 shares	15,727.50				15,727.50
Sears Roebuck & Company	100 shares	6,014.97				6,014.97
Standard Oil Company of New Jersey	200 shares	9,601.26				9,601.26
Union Carbide & Carbon Corporation	100 shares	7,277.42				7,277.42
Total capital stocks		$105,914.04				$105,914.04
Total		$352,178.83	$5,000.00	$5,200.00	$4,253.78	$366,632.61
*Less reserve in full for securities considered to be of doubtful value		7,372.65				7,372.65
Total Securities, Less Reserve		$344,806.18	$5,000.00	$5,200.00	$4,253.78	$359,259.96

Contents of June 1945 Supplement Announced

The five remaining technical papers presented at the 1945 AIEE winter technical meeting and not published in the monthly Transactions sections of *Electrical Engineering*, January to June inclusive, will appear in the June 1945 "Supplement to Electrical Engineering—Transactions Section" soon to be released. The discussions submitted on these papers and on the technical papers published in the January–June monthly sections also will be included in the supplement, completing the publication of papers and discussion presented at the New York winter meeting. All papers and discussions ultimately will be included in the 1945 *Transactions* volume.

Copies of the supplement will be mailed shortly to those who entered advance orders. Others may obtain copies at 50 cents each from the AIEE order department, 33 West 39th Street, New York 18, N. Y., as long as the limited supply lasts.

The following papers which have been abstracted in *Electrical Engineering* will be printed in the supplement:

45-22—Damping and Synchronizing Torques of Power Selsyns; *C. Concordia (M '37), Gabriel Kron (A '30).* Abstracted in the January 1945 issue, page 33.

45-25—The Design of Bus-Bar Industrial Distribution Systems: an Epitomization of Available Data; *T. J. Higgins (A '40).* Abstracted in the January 1945 issue, page 35.

45-43—Field Tests and Performance on Heavy-Duty High-Speed 138-Kv Circuit Breakers—Oil and Air-Blast; *Philip Sporn (F '30), H. P. St. Clair (F '44).* Abstracted in the January 1945 issue, page 38.

45-67—Impedances Seen by Relays During Power Swings With and Without Faults; *Edith Clarke (M '33).* Abstracted in the January 1945 issue, page 37.

45-69—The Resistance-Coupled Amplifier; *L. G. Cowles (A '37).* Abstracted in the January 1945 issue, page 32.

1945 Year Book Issued

The 1945 edition of the AIEE Year Book has been issued, in accordance with 1944–45 budget provisions. Addresses are corrected as of November 1, 1944. Copies have been distributed to all national, District, and Section officers, Student Branch counselors, and all members of national committees. Other members desiring copies may obtain them by writing to the AIEE order department, 33 West 39th Street, New York 18, N. Y. The Year Book is not available to nonmembers of the Institute, nor is its use permitted for commercial, promotional, or other circularization purposes.

National and District Prize Awards for 1944 Announced

Announcement of the 1944 recipients of national prizes for papers was made by F. A. Cowan, chairman of the committee on award of Institute prizes at the annual meeting held in the Engineering Societies' Building, New York, N. Y., on June 27. Personal presentations were made to those who attended. Each national prize award consists of an appropriately engrossed certificate and a check for $100 divided in the case of coauthors. As there was only one eligible paper in the field of public relations and education, no award was made in this class. Also owing to the wartime situation no papers were submitted for the national prize for Branch paper

The awards were as follows:

Best Paper in Engineering Practice: Prize awarded to P. Halpert (A '37) and O. E. Eaval (A '37) of the Sperry Gyroscope Company, Inc., Garden City, N. Y., for their paper, "Electric Automatic Pilots for Aircraft," presented at the 1944 Los Angeles technical meeting, August 29–September 1, and published in the 1944 *Transactions*, pages 861–6. Honorable mention was awarded to H. Winograd (M '39) of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., for his paper, "Development of Excitron-Type Rectifier," presented at the 1944 North Eastern District technical meeting, April 19–20, and the 1944 summer technical meeting, June 26–30, and published in the 1944 *Transactions*, pages 969–78.

Best Paper in Theory and Research: Prize awarded to E. W. Boehne (F '43) of the General Electric Company, Philadelphia, Pa., for his paper, "The Geometry of Arc Interruption—II. Current-Zero Phenomena," presented at the 1944 winter technical meeting, January 24–28, and published in the 1944 *Transactions*, pages 375–87. Honorable mention was awarded to L. J. Berberich (M '36), G. L. Moses (M '44), A. M. Stiles (A '43), and C. G. Veinott (M '34) of the Westinghouse Electric Corporation, East Pittsburgh, Pa., for their paper, "Effect of Altitude on Electric Breakdown and Flashover of Aircraft Insulation," presented at the 1944 winter technical meeting, January 24–28, and published in the 1944 *Transactions*, pages 345–54.

Initial Paper: Prize awarded to L. G. Abraham (M '39), A. J. Busch (M '30), and F. F. Shipley (M '43) of the Bell Telephone Laboratories, Inc., New York, N. Y., for their paper, "Crossbar Toll Switching System," presented at the 1944 winter technical meeting, January 24–28, and published in the 1944 *Transactions*, pages 302–09. Honorable mention was awarded to F. J. Maginniss (A '43) and N. R. Schultz (A '40) for their paper, "Transient Performance of Induction Motors," presented at the 1944 summer technical meeting, June 26–30, and published in the 1944 *Transactions*, pages 641–6.

DISTRICT PRIZES

District prizes for AIEE papers have been announced by four Districts. The awards are for papers presented during 1944. Each District prize consists of an appropriately engrossed certificate and check for $25, divided in the case of coauthors.

District 2

Prize for best paper was awarded to D. Ramadanoff (M '37) and S. W. Glass for their paper, "High-Altitude Brush Problem," presented at a meeting of the Cleveland Section, December 5, 1944.

Prize for initial paper was awarded to W. G. Hall (A '38) for his paper, "Effect of Rotor Skew on Squirrel-Cage-Motor Speed-Torque Characteristics," presented at a meeting of the Cleveland Section, December 5, 1944.

District 6

Prize for best paper was awarded to T. S. Oliver (M '43), N. R. Love (M '38), S. W. Atkins, and H. Sharp (M '31) for their paper, "The Effect of Large Rectifiers on Power-System Wave Shape and Telephone-Circuit Noise," presented at a meeting of the Denver Section, February 18, 1944.

District 9

Prize for best paper was awarded to B. V. Hoard (M '36) and G. W. Bills (A '38) for their paper, "An Analysis to Determine the Optimum Bussing Arrangements and Transmission Capabilities at Grand Coulee," presented at the 1944 Los Angeles technical meeting, August 29–September 1.

District 10

Prize for best paper was awarded to C. K. Duff (M '41) for his paper, "Load, Frequency, and Time Control of Interconnected Systems," presented at a meeting of the Toronto Section, October 26, 1944.

Prize for initial paper was awarded to J. T. Madill (A '41) for his paper "Field Decay Characteristics of Large Hydroelectric Generators," presented at a meeting of the Montreal Section, October 26, 1944.

Officers for 1945-46 Announced at Annual Meeting

Institute officers for the year beginning August 1, 1945, were announced in the report made by the committee of tellers to the annual meeting of the AIEE held in New York, N. Y., June 27. The new officers are:

President: William E. Wickenden, president, Case School of Applied Science, Cleveland, Ohio.

Vice-Presidents: E. S. Fields, vice-president, Cincinnati (Ohio) Gas and Electric Company (District 2, Middle Eastern); H. B. Wolf, superintendent of maintenance, Duke Power Company, Charlotte, N. C. (District 4, Southern); L. M. Robertson, transmission and station engineer, Public Service Company of Colorado, Denver (District 7, South West); F. F. Evenson, consulting engineer, San Diego, Calif. (District 8, Pacific); F. L. Lawton, assistant chief engineer, general engineering department, Aluminum Company of Canada, Ltd., Montreal, Quebec (District 10, Canada).

Directors: J. M. Flanigen, plant engineer, Georgia Power Company, Atlanta; J. R. North, assistant chief electrical engineer, Commonwealth and Southern Corporation, Jackson, Mich.; Walter C. Smith, Pacific district engineer, General Electric Company, San Francisco, Calif.

Treasurer: W. I. Slichter, professor emeritus of electrical engineering, Columbia University, New York, N. Y.

The board of directors for the administrative year beginning August 1, 1945, will consist of the foregoing elected officers and the following holdover officers:

Charles A. Powel, East Pittsburgh, Pa. (*retiring president*); Nevin E. Funk, Philadelphia, Pa. (*junior past president*); C. B. Carpenter, Portland, Oreg.; M. S. Coover, Ames, Iowa; J. F. Fairman, New York, N. Y.; R. T. Henry, Buffalo, N. Y.; R. W. Warner, Austin, Tex. (*vice-presidents*); P. L. Alger, Schenectady, N. Y.; K. L. Hansen, Milwaukee, Wis.; C. M. Laffoon, East Pittsburgh, Pa.; M. J. McHenry, Toronto, Ontario, Canada; C. W. Mier, Dallas, Tex.; S. H. Mortensen, Milwaukee, Wis.; W. B. Morton, Philadelphia, Pa.; D. A. Quarles, New York, N. Y.; W. R. Smith, Newark, N. J. (*directors*).

Additions to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and paid dues for 30 years. A list of those
who have become members for life duri
the preceding year is published annually
Electrical Engineering. Institute members w
have attained this status since publication
the last list in the July 1944 issue are:

R. T. Anderson
R. L. Baldwin
C. P. Banzhof
F. W. Brown
J. W. Brown
J. T. Butterfield
N. A. Carle
F. J. Chesterman
J. C. Clark
J. M. Coahran
W. H. Cole
A. Colvin
P. H. Daggett
R. H. Dalgleish
W. A. Danielson
E. D. Doyle
J. F. Dunn
E. D. Eby
G. E. Edgar
C. C. Egbert
L. R. Elder
F. P. Fahy
H. H. Febrey
A. D. Fishel
I. W. Fisk
G. H. Fletcher
H. Flood, Jr.
W. A. Forbush
E. S. Foster
J. Franz
G. H. Garcelon
M. M. Goldberg
C. W. Green
H. M. Grossman
W. M. Hall
F. Hannaford
F. W. Harris
K. A. Hawley
R. E. Hecker
W. L. Hoffman
S. B. Hood
R. G. Hudson
A. Kennedy
E. E. Kilburn
C. C. Knipmeyer
B. F. Kohlhausen
J. L. Kruger
H. A. Laidlaw
R. C. Landes
O. L. LeFever
W. W. Lewis
G. J. Lipscomb
A. C. Lockwood
F. H. Mason
A. S. Moody
W. C. Nein
A. J. Noer
J. K. Ostrander
R. F. Pack
W. K. Page
W. D. A. Peaslo
L. M. Perrin
F. G. Perry
E. A. Plumer
H. C. Powell
B. Price
C. N. Rakestraw
W. K. Rhodes
L. H. Rittenhou
F. W. Rose
A. M. Rossman
M. W. Sage
F. Sawford
G. B. Schneebe
E. G. Scott
J. W. Sheffer
W. H. Soule
S. A. Staege
W. G. Stearns
A. C. Streamer
H. C. Sutton
G. B. Thomas
F. Thornton, Jr.
W. H. Timbie
O. C. Traver
F. P. Vaughan
O. O. Wagley
H. W. Watt
J. West
J. F. Wiggert
W. J. Williams
C. A. Wolfrom
T. Yensen

SECTION ••••

Philadelphia Section Features Fun at Final Meeting

The annual election of officials for the r
season and four managers, each to serve
terms, and a demonstration of the Am
dyne, together with the presentation c
paper on the subject by John R. William
the General Electric Company, furnished
serious aspect of the final meeting of the A
Philadelphia Section held in May 1
with an attendance of 275. The remai
of the evening was devoted to a program
veloped by the fellowship and attend
committee to promote good fellowship am
the members and to reward those who
been faithful in attendance.

A feature of the entertainment prog
was the awarding of various gifts,
appropriate "pompous" ceremony, to i
viduals whose names were drawn by cha
There was a ticket in the drawing bearing
member's or guest's name for each tech
meeting of the Philadelphia Section or
mington Subsection he had attended,
the receipt of one award disqualified th
cipient from further participation in
contest. Recipients were required to p
their worthiness according to the whin
two gowned and bewigged judges.

During the evening's proceedings a re

tion of thanks, appreciation, and good wishes, signed by all officers and committee chairmen in the Section, was tendered Andrew C. Muir (M '39) retiring chairman.

Panhandle Subsection Organized in Texas

The North Texas Section officially has established the Panhandle Subsection which was organized at Amarillo, Tex., on May 10, 1945, as a result of a petition signed by 14 members in the Panhandle. There were 26 members and interested visitors at the organization meeting at which the following officers were elected:

Chairman: J. G. Ausman (M '45) Southwestern Public Service Company, Amarillo.

Vice-chairman: C. V. Bullen (A '23) Texas Technological College, Lubbock, Tex.

Secretary-Treasurer: D. H. Hickey (A '43) Capitol Hotel, Amarillo.

Official recognition of the Panhandle Subsection was forthcoming when the North Texas Section adopted amendments to its bylaws which authorized the executive committee to establish Subsections and technical groups.

Maryland Section Meets. The May meeting of the Maryland Section of the AIEE this year was held jointly with that of the Maryland Section of the American Society of Mechanical Engineers and was devoted to papers and motion pictures describing the structural, electrical, and mechanical features of the new Riverside generating station of the Consolidated Gas Electric Light and Power Company of Baltimore, Md. At the meeting a booklet containing a foreword and the two papers presented was distributed by that company.

ABSTRACTS • • •

Abstract of Final Summer Paper Received

The following abstract of a summer technical paper was not received in time for publication in the June issue of *Electrical Engineering*.

45-109—Automatic Temperature Control for Aircraft; *R. A. Gund (A '41). 15 cents.* The development of the modern high-speed aircraft has instigated a new application of automatic temperature control, that of controlling the position of cooling flaps. The problem becomes complicated because of the many variable conditions encountered in aircraft operation. Because cooling-flap control is a recent addition to the aircraft industry, there is a need to classify the various basic types of automatic temperature-control systems and to explain briefly their advantages and disadvantages as air-borne equipment. In addition to the aforementioned description a successful aircraft automatic temperature-control system is described.

PERSONAL • • • • •

Charles Edward Skinner (A '99, M '03, F '12) senior electrical engineer, Fort Monmouth (N. J.) Signal Corps Laboratory, and retired assistant director of engineering, Westinghouse Electric Corporation, East Pittsburgh, Pa., was elected an Honorary Member of the Institute, May 29, 1945. Doctor Skinner, who was born May 30, 1865, in Redfield, Ohio, was graduated from Ohio State University with the degree of mechanical engineer in 1890 and holds the honorary degrees of doctor of science (1927) and doctor of engineering (1935) from that university. He commenced his 43-year association with the Westinghouse Company in 1890 as machinist in charge of the manufacture of railway controllers. In 1892 he took charge of inspection and testing of windings, in 1895 of insulation design and testing, and in 1905 of the insulation division. In 1906 he was made head of the research division and in 1920 of the research department. He was appointed assistant director of engineering in 1921, from which position he retired in 1933. Doctor Skinner was responsible for much of the organization and reorganization incidental to the company's growth. He wrote most of the early purchasing-department specifications, organized the insulation division, process engineering work, the research division, and organized and equipped the chemical, physical, and high-voltage laboratories. In 1915 he supervised the building, equipping, and manning of a new research laboratory. His contributions to AIEE affairs have been outstanding. He has held the national offices of president (1931–32), vice-president, and manager and has represented the Institute on the United States National Committee of the International Electrotechnical Commission, the American Engineering Council, the American Association for the Advancement of Science, the Division of Engineering and Industrial Research of the National Research Council, the Iwadare Foundation, the board of management of the World Congress of Engineers, the John Fritz Medal Board of Award, and the Charles Coffin Fellowship and Research Fund Committee. Among the many AIEE committees on which he has served are those on: the Edison Medal, education, electrophysics, Institute policy, research, Standards, and electric machinery. He has participated in many international gatherings of engineers, first going to Brussels in 1906 as American representative of the International Association for Testing Materials. Many times delegate to the International Electrotechnical Commission, he journeyed to Brussels in 1920, Geneva in 1922, The Hague in 1925, and Bellagio in 1927. He was a delegate to the World Power Conference in London in 1924 and the World Engineering Congress in Tokyo in 1929, and he was Iwadare Foundation lecturer in Japan in 1934. He is the author of various papers dealing with insulation, iron testing, and research, and was awarded the Lamme Medal of Ohio State University in 1931. He is a member of Tau Beta Pi, the American Physical Society, the American Society for Testing Materials, the American Society of Mechanical Engineers, the American Association for the Advancement of Science, the Franklin Institute, the American Electrochemical Society and the Engineering Society of Western Pennsylvania.

E. W. Boehne (A '29, F '43) co-ordinator, research and development, Philadelphia (Pa.) Works, General Electric Company, has been awarded the 1944 best paper prize in the field of theory and research for his paper, "The Geometry of Arc Interruption—II. Current-Zero Phenomena." He received the degrees of bachelor of science (1926) and electrical engineer (1940) from the Agricultural and Mechanical College of Texas, and that of master of science (1928) from the Massachusetts Institute of Technology. He was employed by the General Electric Company, Lynn, Mass., in 1926, transferring to Schenectady in 1928 where he made numerous contributions in the field of lightning and surge protection of rotating machines before joining the switchgear-engineering department in 1933. Following assignments on design and development projects, for which he was twice awarded the Charles A. Coffin Award, he was made co-ordinator of research and development. Mr. Boehne received honorable mention in the selection of the outstanding young engineer for 1936 by Eta Kappa Nu and in 1941 received the AIEE District 2 best paper prize for his paper, "The Geometry of Arc Interruption."

O. E. Esval (A '37) director, aircraft instrument research, Sperry Gyroscope Company, Garden City, N. Y., has been awarded the 1944 national prize for best paper in the field of engineering practice as coauthor of the paper, "Electric Automatic Pilots for Aircraft." A graduate of Iowa State College

C. E. Skinner

O. E. Esval

E. W. Boehne

in 1929 with the degree of bachelor of science in electrical engineering, Mr. Esval became associated with the General Electric Company, Schenectady, N. Y., in that same year in the student test course, subsequently accepting the position of engineer in the motor-engineering department. In 1931 he joined the engineering department of the Sperry Gyroscope Company to work in the fire-control department and the research laboratory. Mr. Esval is a member of the Institute of Aeronautical Sciences and the National Aeronautic Association. He is the author of several technical papers.

Percy Halpert (A '37) project engineer, Sperry Gyroscope Company, Inc., Garden City, N. Y., has been awarded the 1944 national best paper prize in the field of engineering practice as coauthor of the paper, "Electric Automatic Pilots for Aircraft." Mr. Halpert was graduated from the College of the City of New York with the degree of bachelor of science in engineering in 1935, and he received the degree of electrical engineer in 1936. Following graduation he accepted a position with Aerovox Corporation, Brooklyn, N. Y., as supervisor in charge of wet electrolytic capacitor anode formation. In 1937 he became test engineer for the Sperry Gyroscope Company, Inc., was appointed to the laboratory staff in 1938 for research and development in automatic controls, and was made research engineer in charge of flight-control research in 1942.

F. F. Shipley (M '43) technical staff member, Bell Telephone Laboratories, Inc., New York, N. Y., has been awarded the national 1944 best paper prize in the initial-paper field as coauthor of the paper, "Crossbar Toll Switching System." After graduating with a bachelor-of-science degree in electrical engineering in 1925 from Purdue University, Mr. Shipley became a member of the department of development and research of the American Telephone and Telegraph Company, New York. Here he worked on toll-switching problems and patent studies, and in 1934 accepted the position as a member of the technical staff of Bell Telephone Laboratories.

L. G. Abraham (M '39) communications engineer, Bell Telephone Laboratories, Inc., New York, N. Y., has been awarded the national 1944 best paper prize for initial paper as coauthor of the paper, "Crossbar Toll Switching System." Mr. Abraham received the degrees of bachelor of science in 1922 and master of science in 1923, both in electrical engineering, from the University of Illinois. In 1923 he joined the department of development and research of the American Telephone and Telegraph Company, New York, N. Y., as a member of the transmission development department and was transferred to the Bell Telephone Laboratories in 1934. His work has been chiefly in connection with toll circuits and has been particularly directed toward securing optimum over-all performance of telephone message connections.

A. J. Busch (A '24, M '30) member of the technical staff, Bell Telephone Laboratories, Inc., New York, N. Y., has been awarded the national 1944 best paper prize for initial paper as coauthor of the paper, "Crossbar Toll Switching System." Mr. Busch was graduated with the degree of electrical engineer in 1922 from the Polytechnic Institute of Brooklyn. He was first employed as development engineer in the engineering department of the Western Electric Company, New York, N. Y., until 1925 when he became a member of the technical staff of the Bell Telephone Laboratories. Since 1941 he has supervised a development group engaged in the design of automatic telephone switching systems and in charge of communications work for the Armed Forces.

C. G. Veinott (A '28, M '34) special development engineer, Westinghouse Electric Corporation, Lima, Ohio, has received honorable mention in the 1944 national best paper prize award in the field of theory and research, as coauthor of the paper, "Effect of Altitude on Electric Breakdown and Flashover of Aircraft Insulation." He was graduated in 1926 from the University of Vermont with a bachelor-of-science degree in electrical engineering and in that same year began a student graduate course with Westinghouse Electric Corporation, East Pittsburgh, Pa., where he subsequently did development work in the office of the chief electrical engineer and became instructor in the electrical department of the technical night school. In 1929 he was transferred to East Springfield, Mass., in the small-motor engineering department, in 1931 became electrical design engineer, and in 1937 was transferred again, this time to Lima, Ohio, to become design and application engineer. In 1936 Mr. Veinott received honorable mention in connection with the selection of America's outstanding young engineer for that year, by Eta Kappa Nu, and in 1938 he was awarded the degree of electrical engineer from the University of Vermont. He has served on the AIEE committee on electronics and is an active member of that on electric machinery. He is the author of several technical papers.

L. J. Berberich (A '30, M '36) section engineer, insulation department, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has received honorable mention in the 1944 national prize award in the field of theory and research, as coauthor of the paper, "Effect of Altitude on Electric Breakdown and Flashover of Aircraft Insulation." He was graduated from Johns Hopkins University, receiving the degrees of bachelor of engineering in 1928, and doctor of engineering in 1931. From 1927 to 1931 he was at various times employed as student engineer by the Westinghouse Electric Corporation, as junior engineer by the National Bureau of Standards, Washington, D. C., and as research assistant by Johns Hopkins University, Baltimore, Md. In 1931 he became associated with the research and development division of the Socony-Vacuum Oil Company, Inc., Paulsboro, N. J., as research engineer, in 1941 became group leader, and in 1943 was made section engineer in charge of the physical and electrical section. Doctor Berberich is the author of several technical papers and the holder of a number of patents. He has served as a member of the AIEE committee on research and is now a member of the subcommittee on insulation resistance of the AIEE committee on electric machinery.

Harold Winograd (A '26, M '39) engineer in charge, rectifier design, electrical department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has received honorable mention in the 1944 national prize awards, in the field of engineering practice for his paper, "Development of Excitron-Type Rectifier." Born September 12, 1900, in Russia, Mr. Winograd was graduated from Cornell University in 1924 with the degree of electrical engineer. In 1925 after a year and a half in the test department of the United Electric Light and Power Company, New York, N. Y., he joined the American Brown Boveri Electric Corporation, Camden, N. J., where he was employed as

A. J. Busch

L. G. Abraham

Percy Halpert

F. F. Shipley

rectifier engineer. In 1931 he accepted a position with the Allis-Chalmers Company which in that year acquired the Brown Boveri Company, supervising the design of rectifier equipment. Mr. Winograd is coauthor of the book, "Mercury-Arc Power Rectifiers," is the author of several technical papers and the holder of a number of patents, and is now serving on the AIEE committee on electronics.

G. L. Moses (A '43, M '44) manager, development insulation section, a-c engineering department, transportation and generator division, Westinghouse Electric Corporation, East Pittsburgh, Pa., has received honorable mention in the 1944 national best paper prize award in theory and research, as coauthor of the paper, "Effect of Altitude on Electric Breakdown and Flashover of Aircraft Insulation." He graduated from the Bliss Electrical School in 1923 and has been with the Westinghouse Corporation since that time. In 1923 he was a student in the graduate training course, in 1924 he became sales correspondent of railway sales, later was promoted to railway control engineer, and in 1937 he became coil and insulation engineer in the transportation and generator engineering department. In 1942 he was named engineer in charge, insulation development group, transportation and generator engineering department. Mr. Moses has contributed a number of papers to technical publications.

A. M. Stiles (A '43) engineer, rectifier section, a-c generator engineering department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has received honorable mention in the national 1944 best paper prize in theory and research, as coauthor of the paper, "Effect of Altitude on Electric Breakdown and Flashover of Aircraft Insulation." He received the degree of bachelor of science in electrical engineering from Iowa State College in 1941 and was awarded the master-of-science degree in electrical engineering from Carnegie Institute of Technology in 1942. In 1941 he was a graduate research fellow and assisted in faculty research at the Carnegie Institute of Technology, Pittsburgh, Pa., and in 1942 became a special graduate student engineer for the Westinghouse Corporation, assigned to the insulation department of the research laboratories. In that same year he was made a junior research engineer, working in insulating materials and allied fields of electrical measurements.

F. J. Maginniss (A '43) central-station engineering division, General Electric Company, Schenectady, N. Y., has received honorable mention in the 1944 best paper prize award for initial paper as coauthor of "Transient Performance of Induction Motors." He was graduated with the degree of bachelor of science from New York University in 1937 and received the master-of-science degree from the University of Pennsylvania in 1940. In 1939 he became research assistant, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, and in 1940 accepted the position as junior physicist, Frankford Arsenal, Philadelphia. In 1941 he became associated with the General Electric Company as electrical engineer in charge of the operation of the differential analyzer.

N. R. Schultz (A '40) electrical engineer, central-station engineering division, General Electric Company, Schenectady, N. Y., has received honorable mention in the 1944 national best paper prize award for initial paper, as coauthor of "Transient Performance of Induction Motors." Mr. Schultz was graduated from the University of Colorado in 1939 with a bachelor-of-science degree and in that year became student engineer, testing electrical equipment in the General Electric Company. In 1941 he was transferred to the central-station engineering division.

P. B. Garrett (A '24, M '30) formerly of the northwestern engineering division of the Westinghouse Electric Corporation, Chicago, Ill., has become editor of *Electric Light and Power*, Chicago. A graduate of Colorado State College, Mr. Garrett joined the Westinghouse Company as a student engineer about 1922 and has served since as district engineer in San Francisco, Calif., and as general engineer in the Salt Lake City, Utah, and Butte, Mont., territories of the company.

C. C. Rathgeb (A '21, M '23) formerly vice-president and managing director, Canadian Comstock Company, Ltd., Toronto, Ontario, Canada, has been appointed president of the company. Mr. Rathgeb, who was born in Port Chester, N. Y., in 1892, joined the company in New York, N. Y., as assistant superintendent of construction in 1910. He became superintendent of construction about 1920 and was appointed vice-president in 1926.

W. W. Parker (A '30, M '37) electrical engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed regional engineer of the Rio de Janeiro office of the Westinghouse Electric International Company. Mr. Parker joined the Westinghouse Company as a member of the student engineering course upon his graduation from Sheffield Scientific School of Yale University in 1927 and later was transferred to the switchgear division.

J. K. Bradford (A '33) lieutenant colonel, Canadian Active Service Force, has returned to the staff of Canada Wire and Cable Company, Ltd., Toronto, Ontario, Canada. Colonel Bradford enlisted as a lieutenant in 1939, served in Sicily and Italy with the Royal Canadian Engineers, and was detached for special duty in the Normandy landing. He has received the Order of the British Empire.

A. F. Morairty (A '43) vice-president, Central Arizona Light and Power Company, Phoenix, has been given charge of public-relations work, postwar planning, and industrial development as the result of a recent reassignment of duties among the company's executives. **G. G. Groh** (M '43) general superintendent, has been given the additional duties of chief engineer in charge of all operations, construction, and maintenance.

T. H. Crosby (M '37) district manager, Canadian Westinghouse Company, Ltd., Vancouver, British Columbia, Canada, has been elected president of the Electrical Service League of British Columbia.

OBITUARY • • • • •

Philip Green Gossler (A '94, M '98, F '13) chairman of the board, Columbia Gas and Electric Corporation, New York, N. Y., died May 18, 1945. Born at Columbia, Pa., August 6, 1870, Mr. Gossler received the degrees of bachelor of science in 1890 and electrical engineering in 1892 from Pennsylvania State College. He accepted positions wih the Chester (Pa.) Foundry and Machine Company, and the Edison General Electric Company, New York, between the years 1890–91, and then became assistant engineer of the United Electric Light and Power Company, New York. From 1895 to 1901 he was superintendent and engineer of the Royal Electric Company, Montreal, Quebec, Canada, and in the latter year left to become general superintendent and engineer for the Montreal Light, Heat and Power Company. In 1904 he was named vice-president of J. G. White and Company, New York, and in 1909 became chairman of the board of the Columbia Gas and Electric Company, which was the nucleus of the Columbia system developed under his leadership. In 1926 Mr. Gossler helped direct the merger of the Ohio Corporation and Columbia into the Columbia Gas and Electric Corporation. He served as president of the corporation from 1926 until 1936, when he became chairman of the board. He was a director of the Guaranty Trust Company, trustee of the Edison Electric Institute, former vice-president of the Edison Pioneers and the New York Electrical Society, and a member of the American Gas Association, and Association of Edison Illuminating Companies. He has served as a member of the AIEE committees on local organizations, National Electric Code, and conservation of natural resources.

Bradley Thomas McCormick (A '04, M '09, F '13) electrical engineer, Wagner Electric Corporation, St. Louis, Mo., died April 20, 1945. He was born May 28, 1880, in Marietta, Ohio, and received his education at Cornell University, graduating in 1903 with the degree of mechanical engineer. In 1903 he entered the employ of the Bullock Electric Manufacturing Company, Cincinnati, Ohio, where he received a training course in the shops and later was transferred to the engineering department as design engineer. In 1906 he accepted the position as chief electrical engineer of Allis-Chalmers–Bullock, Ltd., Montreal, Quebec, Canada, in charge of the electrical and mechanical design of electric machinery, and from 1913 until 1915 he was a member of the firm Forbes and McCormick, Montreal. Between the years 1915–17, he was chief engineer of the Mississippi Valley Metal Products Company, St. Louis, Mo., and during World War I, served as a captain and was advanced to the rank of major in the Ordnance Department of the United States Army. In 1919 he became associated with the Wagner Electric Corporation, where, until his death, he alternated between the positions of supervisor of the small-motor engineering department and assistant to the consulting engineer. He was active in the AIEE St. Louis Section and for several years was chairman.

Claude Joseph Holslag (M '19, F '41) president, Electric Arc Cutting and Welding

Company, Newark, N. J., died June 11, 1945. Born at Addison, N. Y., in 1885, he was graduated from Columbia University in 1908 with a degree in electrical engineering. After graduation he entered the electrical-engineering department of the New York Central Railroad, later becoming resident engineer at Amsterdam, N. Y., working on the experimental track there. He continued with the railroad as assistant electrical engineer until 1918, but also was associated with organizations engaged in the manufacture of electrodes since 1915, having helped to organize the Steinbach Electric Company (renamed the Splitdorf Electric Company in 1917). At that time he acted as general manager and later chief engineer. When the Steinbach Company became the Electric Arc Cutting and Welding Company in 1918, Mr. Holslag was named president. He was awarded the Samuel Wylie Miller Medal in 1938 and the Modern Pioneer Award in 1940. Mr. Holslag was a member of the American Electrochemical Society, American Welding Society, the National Electrical Manufacturers Association, and was on the board of managers for the Columbia Engineering School. He was the holder of many patents in the welding industry, and he served as a member of the AIEE committee on electric welding from 1927 to 1931 and from 1934 to 1939.

George Curtis Barney (M '37) operation and engineering department, American Telephone and Telegraph Company, New York, N. Y., died May 11, 1945. Mr. Barney was born at Berlin, N. H., April 21, 1899. In 1917 he left the University of Maine to join the United States Naval Reserve and served during World War I as second in charge of a radiotelegraph station at Poitiers, France. During the winter of 1920–21 he was in charge of radiotelegraph operations at Vienna, Austria, for the United States War and Navy Departments. In 1921 he returned to the United States and resumed his studies at the University of Maine from which he was graduated in 1924. On leaving college, he joined the New England Telephone and Telegraph Company, Providence, R. I., in 1927 was made division transmission engineer, and in 1929 transferred to the transmission-engineering section of the American Telephone and Telegraph Company, New York. From 1935 until 1938 he served in Europe as assistant to the technical representative of that company and Bell Telephone Laboratories, Inc., with headquarters at London, England. Upon completion of this work, he returned to the American Telephone and Telegraph Company and in 1942 was transferred to the foreign-wire-relations section. He was a member of the Telephone Pioneers of America.

Harry C. Brown (A '20) planning engineer, Crossett (Ark.) Paper Mills, died February 21, 1945. Born July 2, 1890, at Amherst, N. J., he was graduated from McGill University in 1917 with a bachelor-of-science degree in electrical engineering. In 1918 he accepted a position working with power and cable design for the Northern Electric Company, Montreal, Quebec, Canada, in 1919 he was transferred to station-design work for the Hydro-Electric Power Commission, Toronto, Ontario, Canada, and in 1920 became electrical engineer for the Belgo Canadian Pulp and Paper Company, Ltd., Shawinigan Falls, Quebec. In 1924 he worked in the same capacity for the Newfoundland Power and Paper Company, Corner Brook, and was advanced to manager of power development in 1926. He left in 1929 to accept the appointment of electrical engineer for the manufacturing department of the International Paper Company, New York, N. Y., and later was promoted to chief electrical engineer. In 1937 Mr. Brown was an electrical engineer at the New York (N. Y.) World's Fair, Inc., in 1941 he was affiliated with the Union Bag and Paper Corporation, Savannah, Ga., and in 1943 became associated with the Crossett Paper Mills.

Samuel Albert Spalding (A '05, F '29) chief engineer, Gibbs and Hill, New York, N. Y., died May 25, 1945. Born February 23, 1873, in Danvers, Mass., Mr. Spalding was graduated with the degree of bachelor of electrical engineering in 1894 from Tufts College. In 1896 he became assistant engineer with the Brooklyn (N. Y.) Rapid Transit System, in 1903 accepted the position of transmission engineer for the New York Central System, New York, N. Y., engaged in the electrification of Grand Central Terminal, and in 1904 returned to the Rapid Transit System to become superintendent of power. In 1909 he served as assistant engineer with the Pennsylvania Tunnel and Terminal Railroad Company, New York, N. Y., and in 1910 was appointed chief engineer for Gibbs and Hill. As chief engineer, Mr. Spalding supervised such projects as the electrification of the Pennsylvania Railroad and the Virginian Railway and was consultant in connection with the Illinois Central Railroad electrification and the design and construction of electrification of the New York Connecting Railroad. He served as a member on the AIEE transportation committee and the board of examiners.

Warren Rhodes Hill (A '24) chief electrical engineer, Aluminum Company of America, Edgewater, N. J., died April 11, 1945. Born April 17, 1895, at Nashua, N. H., Mr. Hill was graduated with the degree of bachelor of science in electrical engineering from Worcester Polytechnic Institute in 1922. Upon graduation he became assistant engineer, engineering department, for the United Electric Light and Power Company, New York, N. Y., and subsequently was named assistant engineer, design division, transmission and distribution department of that company. He was employed by the company for several years until he accepted a position in the same capacity for the New York Edison Company, New York, and he remained with that company as assistant engineer when it became the Consolidated Edison Company of New York, Inc., in 1936. He was associated with the Edison Company until 1944 at which time he was appointed chief electrical engineer for the Aluminum Company of America.

Clayton A. Barger (A '44) field engineer, American Ship Building Company, Cleveland, Ohio, died April 2, 1945. He was born October 11, 1892, at Spring Mills, Pa., and in 1911 became an electrical apprentice for the Cambria Steel Company, Johnstown, Pa. From 1915 to 1920 he was associated with the American Ship Building Company, Lorain, Ohio, first as an electrician and subsequently as maintenance foreman. In 1921 he organized his own company and in 1926 returned to the American Ship Building Company, Cleveland, as assistant chief electrician, where he remained until 1931. In 1932 he was appointed sales manager for the Genuine Auto Parts Company, Lorain, in 1938 became general foreman for Germaine and Smith, general contractors, Hiram, Ohio, and in 1942 again returned to the American Ship Building Company, in the Buffalo (N. Y.), and Lorain offices, where he was chief electrician and later field engineer.

Lionel Hoechstetter (A '35) engineering department, Fairchild Aircraft Corporation, Hagerstown, Md., died May 8, 1945. He was born October 1, 1909, at Pittsburgh, Pa., and received his education at Carnegie Institute of Technology, graduating in 1932 with a bachelor-of-science degree in electrical engineering. In 1933 he became manager of the radio department for McCreery and Company, Pittsburgh, and left in 1934 to do inventory work with M. R. Scharff, consulting engineer, New York, N. Y. In 1935 he accepted the position of property record engineer, Westchester Lighting Company, New York, and in 1936 was promoted to junior engineer. In 1937 he was appointed electrical engineer for the Electricoil Company, New York, in which position he remained until 1941, when he became associated with the Fairchild Aircraft Corporation as an electrical engineer.

Harold Childs Pease (A '03) designing engineer engaged in war work, Armstrong Cork Company, Lancaster, Pa., died May 5, 1945. Born in Charlestown, Mass., in 1874, he attended Cornell University and was graduated with a degree in electrical engineering in 1897. He became associated with the General Electric Company, Schenectady, N. Y., soon after graduation, and in 1922 was transferred to the Erie (Pa.) plant as assistant engineer of the control department. He was subsequently made manufacturing engineer of drum controls and remained in that capacity until he was retired from the General Electric Company in 1936. In that same year he joined the Hamilton Watch Company, Lancaster, as experimental engineer of the machine experimental department and retired from that company in 1942, at which time he entered the employ of the Armstrong Cork Company.

Christopher Meyer Lowther (A '00) retired electrical engineer, New York, N. Y., died April 12, 1945. He was born in New York, May 7, 1874, and was graduated from Columbia University in 1898 with the degree of electrical engineer. Early in his career he served the Bank of New Amsterdam, New York, N. Y., and after graduation from the university he entered the employ of the Static Carbonating Company, working on liquefied-carbonic-acid pressure gauges and on machines. He left to become associated with the Crocker-Wheeler Electric Manufacturing Company, Ampere, N. J., where he did special testing, draughting and engineering, and was later promoted to sales engineer. Mr. Lowther left the Crocker-Wheeler Company to represent the Duncan Meter Company, New York, N. Y., and later continued activities for Lowther and Sons, a coal business founded by his father.

Truman Preston Brewster (M '44) superintendent of telegraph, Atchison, Topeka, and Sante Fe Railway Company, Chicago, Ill., died January 7, 1945. He was born January 28, 1893, at Azusa, Calif. He was first associated with the company in 1925, when he accepted the position of telegraph and telephone supervisor at Los Angeles, Calif. In 1929 he was promoted to assistant superintendent, in direct charge of communications personnel and facilities for the lines west of Albuquerque, N. Mex. In 1929 Mr. Brewster was transferred to the Chicago offices to become superintendent in charge of the telegraph department, embracing all communication personnel, construction, maintenance, and operation.

William Samuel Booth (A '44) lieutenant, junior grade, United States Naval Reserve, died May 3, 1945 while on active duty. Lieutenant Booth was born September 18, 1920, in Cambridge, Ohio, and was graduated from Ohio State University in 1943 with a degree in electrical engineering. Upon graduation, he was commissioned an ensign, United States Naval Reserve, and was assigned to duty as administrative assistant for the Naval Research Laboratory, Washington, D. C. His work consisted of all phases of radio research and development, and preparation of technical reports and monographs on all types of radio equipment. He was advanced to the rank of lieutenant, junior grade, in 1944. He was an associate of the Institute of Radio Engineers.

Andrew J. Symbolie (A '42) electrician, Watervliet (N. Y.) Arsenal, died in April 1945. He was born February 22, 1891, at Troy, N. Y. In 1906 he became an electrical contractor for E. G. Benard of Troy and in 1915 worked in the same capacity for H. L. Jewell, Albany, N. Y. In 1916 he served in the United States Army, and in 1917 went in business for himself as an electrical contractor. In 1918 he accepted the position as electrician for the Watervliet Arsenal, left there in 1920 to go on with his own business, and returned to the Arsenal in 1939 to become leader electrician.

Robert Rieman Harvey (A '95) retired electrical engineer, died February 20, 1945, at Wilkes-Barre, Pa. He was born on December 1, 1871, at Wilkes-Barre, and was graduated with a bachelor-of-science degree from Lehigh University in 1895. In 1896 Mr. Harvey became associated with the Westinghouse Electric and Manufacturing Company in the capacity of electrical engineer, first with their offices in Pittsburgh, Pa., and subsequently in Buffalo, N. Y. In 1898 he became general superintendent for the Columbia Mills, Inc., Wilkes-Barre and in later years retired from that position.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners, at its meeting on May 24, 1945, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Griffith, H. C., asst. chief engr., Pennsylvania Railroad, Philadelphia, Pa.

1 to grade of Fellow

To Grade of Member

Armstrong, J. F., asst. to general supt., El Paso Elec. Co., El Paso, Texas
Barnes, F. P., district representative, General Elec. Co., San Francisco, Calif.
Berry, W. S., asst. elec. engr., Underwriters Labs., Inc., New York
Berting, G. A., asst. to pres., The North Electric Mfg. Co., Galion, Ohio
Bonine, C. E., consulting engr., Philadelphia, Pa.
Bound, P. T., engr., Canadian Westinghouse Co. Ltd., Hamilton, Ont.
Brancato, E. L., assoc. elec. engr., U. S. Navy Yard, Brooklyn, N. Y.
Canning, G. R., protection engr., Ohio Bell Tel. Co., Cleveland, Ohio
Corwith, H. P., asst. chief engr., Western Union Telegraph Co., New York
Currie, G. J., plant training supervisor, Ohio Bell Tel. Co., Cleveland, Ohio
Darcey, J. F., supt. of maintenance and distribution, Capital Transit Co., Washington, D. C.
Daugherty, Frank, pres. and chief engr., Scofield Engg. Co., Philadelphia, Pa.
Daugherty, R. H., engr., American Tel. & Tel. Co., New York
Deardorff, H. E., supervisor, Dayton Power & Light Co., Dayton, Ohio
Diemond, C. C., chief, Relay Unit, Bonneville Pwr. Administration, Portland, Oreg.
Dobrick, F. S., engr. in charge, Reliance Elec. & Engg. Co., Cleveland, Ohio
Dodds, G. B., relay protection engr., Duquesne Light Co., Pittsburgh, Pa.
Dougherty, H. P., division plant supt., Southwestern Bell Tel. Co., St. Louis, Mo.
Evans, S. O., elec. engr., Babcock & Wilcox Tube Co., Beaver Falls, Pa.
Ferree, H. M., test supervisor, General Elec. Co., Cleveland, Ohio
Fuller, J. L., experimental engr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Gilbert, P. G., district engg. div., Westinghouse Elec. Corp., Philadelphia, Pa.
Green, R. C., elec. engr., Naval Ordnance Lab., Navy Yard, Washington, D. C.
Guildford, R. P., Middle Atlantic electrical supt., Westinghouse Elec. Corp., Philadelphia, Pa.
Guldi, F. G., engr., Public Service Elec. & Gas Co., Newark, N. J.
Harris, J. B., pres., Rumsey Elec. Co., Philadelphia, Pa.
Headley, F. L., district mgr., General Elec. Co., Philadelphia, Pa.
Hemeter, L. H., service engr., Aluminum Company of America, Pittsburgh, Pa.
Hines, C. M., elec. engr., Westinghouse Air Brake Co., Wilmerding, Pa.
Hull, R. B., chief electrician, General Motors Corp., Anderson, Ind.
Inman, D. E., Engg. & Service Mgr., Westinghouse Elec. Corp., Cleveland, Ohio
Kanzler, W. H., Chief, Engg. and construction div., Bonneville Pwr. Administration, Portland, Oreg.
Kirk, E. L., elec. engr., Dow Chemical Co., Midland, Mich.
Lang, J. S., elec. engr., Automatic Temperature Control Co., Philadelphia, Pa.
Leonard, S. E., engr.-in-charge, National Broadcasting Co. Inc., Cleveland, Ohio
Martin, H. C., vice-pres. and chief engr., The Ambos-Jones Co., Cleveland, Ohio
Marx, C. J., engr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Moss, S. A., general plant supervisor, Chesapeake & Potomac Tel. Co., Washington, D. C.
Myles, A. H., asst. chief engr., Elec. Controller & Mfg. Co., Cleveland, Ohio
Oetting, R. L., illuminating engr., General Elec. Co., Cleveland, Ohio
Orcutt, H. S., industrial engr., Federal Tel. & Radio Corp., Clifton, N. J.
Perry, M. L., associate elec. engr., Black & Veatch, Kansas City, Mo.
Phelps, H. S., engr., Philadelphia Elec. Co., Philadelphia, Pa.
Picking, J. W., electronics development engr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Plumley, H. J., physicist, Naval Ordnance Lab., Washington, D. C.
Porter, W. J., engr.-in-charge, Small Motor Engg. Dept., Canadian Westinghouse Co., Hamilton, Ont.
Schlough, F. H., engr. of equipment, Bell Tel. Co. of Pa., Pittsburgh, Pa.
Schmidt, A. W., asst. chief, Bureau of Reclamation, Denver, Colo.
Setter, J. A., industrial elec. engr., General Elec. Co., Denver, Colo.
Short, H. D., elec. engr., Canada Wire & Cable Co. Ltd., Toronto, Ont.
Slemmer, W. E., transmission and distribution engr., Public Service Co. of Oklahoma, Tulsa
Staller, A. W., factory manager, Crescent Insulated Wire & Cable Co., Trenton, N. J.
Stocker, C. P., vice-president and chief engr., Lorain Products Corp., Lorain, Ohio
Swanson, E. H., supervisor, research & development lab., S. S. White Dental Co., Staten Island, N. Y.
Threm, A. G., laboratory technician, Public Service Elec. & Gas Co., Maplewood, N. J.
Tiernan, T. F., elec. engr., American District Telegraph Co., New York
Tovee, E. H., elec. engr., Canadian Westinghouse Co. Ltd., Hamilton, Ont.
Trant, J. L., chief engr., The Brown-Brockmeyer Co., Dayton, Ohio
Van Lund, J. A., design and development engr., General Elec. Co., Pittsfield, Mass.
Vogeler, R. A., mgr., Federal Tel. & Radio Corp., Chicago, Ill.
Weesner, R. J., D. C. product development engr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Winsor, L. P., instructor, Case School of Applied Science, Cleveland, Ohio

62 to grade of Member

The board of examiners, at its meeting on June 14, 1945, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Boyce, F. G., vice-president in charge of construction and operation of power plants, Consumers Power Co., Jackson, Mich.
Cook, L. E., general engr., Ebasco Services, Inc., New York
Crumpton, W. J., member of patent staff, Bell Tel. Labs., Inc., New York
Edison, O. E., prof. of elec. engg., Univ. of Nebraska, Lincoln, Nebr.
Hamilton, H. C., head of test & research section, Boston Edison Co., Boston, Mass.
Lumley, C. S., engg. mgr., Smith, Hinchman & Grylls, Inc., Detroit, Mich.
Norris, F. W., prof. of elec. engg., Univ. of Nebraska, Lincoln, Nebr.
Rotty, O. J., system supt., Union Electric Co. of Missouri, St. Louis, Mo.
Sels, H. K., transmission & substation engr., Public Service Elec. & Gas Co., Newark, N. J.
Taylor, D. W., asst. elec. engr., Public Service Elec. & Gas Co., Newark, N. J.
Wilbraham, R. W., chief elec. engr., United Engineers & Constructors, Inc., Philadelphia, Pa.
Zworykin, V. K., associate research director, RCA Labs., Princeton, N. J.

12 to grade of Fellow

To Grade of Member

Austin, D. R., consulting elec. engr., Radar Section, S. A. Defence Force, Johannesburg, So. Africa
Bailey, C. A., designing engr., General Elec. Co., Schenectady, N. Y.
Bender, J. B., technical inspection supervisor, Emerson Elec. Mfg. Co., St. Louis, Mo.
Best, P. B., application engr., A. G. Redmond Co., Owosso, Mich.
Betz, P. L., research engr., Consolidated Gas, Elec. Lt. & Pwr. Co., Baltimore, Md.
Bloomquist, W. C., application engr., General Elec. Co., Schenectady, N. Y.
Buck, A. M., elec. engr., Weyerhaeuser Timber Co., Everett, Wash.
Buess, L. E., technical field engr., General Elec. Co., Cleveland, Ohio
Cantwell, J. L., development engr., General Elec. Co., Pittsfield, Mass.
Cartmell, A. W., elec. engr., Pasadena Light & Power Co., Pasadena, Calif.
Chappuis, C. K., major, Air Corps, U. S. Army, Washington, D. C.
Clark, C. N., distribution section engr., Duquesne Light Co., Pittsburgh, Pa.
Clarke, H. A., elec. engr., Appalachian Electric Power Co., Charleston, W. Va.
Clements, S. E., Major, Signal Corps, Washington, D. C.
Cobert, C. S., application engr., Clark Controller Co., Cleveland, Ohio
Crever, F. E., asst. division engr., General Elec. Co. Schenectady, N. Y.
Daniels, H. C., plant engr., Chase Brass & Copper Co., Cleveland, Ohio
Feeney, R. J., elec. engr., The Ohio Public Service Co., Elyria, Ohio
Flynn, J. V., application engr., Master Electric Co., Dayton, Ohio
Goss, F. L., engr. of overhead distribution, Dept. of Water & Power, City of Los Angeles, Calif.
Greenleaf, E. R., transmission and outside plant engr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Hall, J. I., elec. engr., Trumbull Elec. Mfg. Co., Plainville, Conn.
Hall, W. G., mgr. of renewal parts div., Reliance Elec. & Mfg. Co., Cleveland, Ohio
Hancock, M. S., mgr. of engg., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Hardenbergh, B., distribution supt., The Ohio Public Service Co., Lorain, Ohio
Hubbell, M. F., Major, Ordnance Dept., St. Louis, Mo.

Johnson, I. B., research and development, General Elec. Co., Schenectady, N. Y.
Kennedy, E. R., chief draftsman, Puget Sound Bridge & Dredging Co., Seattle, Wash.
Kent, P. J., chief engr., Chrysler Corp., Detroit, Mich.
Koch, C. J., engr., General Elec. Co., Schenectady, N. Y.
Kutcher, W. J., elec. engr., Electrical Controller & Mfg. Co., Cleveland, Ohio
Lang, W. Y., member of technical staff, Bell Tel. Labs., Inc., New York
Ludwick, W. L., director, technical div., The Peck, Stow & Wilcox Co., Southington, Conn.
McLachlan, W. J., engr., General Elec. Co., Schenectady, N. Y.
Metcalf, E. C., machinery inspector, Fidelity & Casualty Co. of N. Y., Omaha, Nebr.
Nowacki, L. M., asst. section engr., General Elec. Co., Schenectady, N. Y.
O'Connor, J. V., elec. engr., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Phillips, A. F., senior engr., Duquesne Light Co., Pittsburgh, Pa.
Preston, W. F., asst. chief engr., Cia Aux de Empresas Eletricas Brasileiras, Brazil, So. America
Quick, D. M., asst. engr., Public Service Elec. & Gas Co., Newark, N. J.
Raysdale, W. H., field service engr., General Motors Corp., Flint, Mich.
Scholz, W. E., engr., Philadelphia Elec. Co., Philadelphia, Pa.
Shere, G. D., chief engr., Electrical Specialty Co., Boston, Mass.
Sherman, K. S., transmitter engr., WGAR Broadcasting Co., Cleveland, Ohio
Simpson, J. H., junior research engr., National Research Council, Ottawa, Ont., Canada
Smith, H. C., maintenance and circuit engr., The Ohio Bell Tel. Co., Cleveland, Ohio
Spinks, A. W., associate physicist, National Bureau of Standards, Washington, D. C.
Stewart, J. A., Major, Signal Corps, San Francisco, Calif.
Thompson, Ernest, elec. engr. and associate, E. A. Schmidt & Co., St. Louis, Mo.
Thurman, A. L., steel mill application engr., General Elec. Co., Schenectady, N. Y.
Uffelman, W. R., district mgr., Bodine Electric Co. of Chicago, Cleveland, Ohio
Whitman, L. C., development engr., General Elec. Co., Pittsfield, Mass.
Wyeth, F. H., elec. engr., Leeds & Northrup Co., Philadelphia, Pa.
Yost, I. A., mgr. of engg., Westinghouse Elec. Corp., Cleveland, Ohio

54 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the national secretary before August 15, 1945 or October 15, 1945, if the applicant resides outside of the United States or Canada.

To Grade of Member

Bank, M. L., Fischbach & Moore of Texas, Inc., Dallas, Texas
Berget, E. A., 1st Lieut., U.S.M.C., San Diego, Calif.
Bhasin, O. P., United Provinces Govt., Roorkee, India
Bovey, D. E., Woodward Governor Co., Rockford, Ill.
Churchill, W. W., Gen. Elec. Co., Schenectady, N. Y.
Clinton, J. S., Salisbury Electricity Dept., Salisbury, Southern Rhodesia
Cunningham, C. T., Reconstruction Fin. Corp., Washington, D. C.
Dana, H. J., Wash. State Col., Pullman, Wash.
Dovey, E. J., Duquesne Light Co., Pittsburgh, Pa.
Duryea, H. (Re-election), Commonwealth & Southern Corp., Birmingham, Ala.
Earl, R. B., Jr., D. R. Warren Co., San Francisco, Calif.
Frank, W. H., Bulldog Elec. Prod. Co., Detroit, Mich.
Holsgrove, H. E., A. C. Cossor, Ltd., London, England
Jamison, G. B., Crouse Hinds Co., Houston, Texas
Kressly, M. E., Gilbert Associates, Inc., Reading, Pa.
Kumar, S. S., Public Works Dept., Lahore, Punjab, India
Lauder, D. H., Gen. Elec. Co., Schenectady, N. Y.
Lewis, R. R., Tenn. Val. Auth., Watts Bar Dam, Tenn.
Makous, L. (Re-election), A. O. Smith Corp., Milwaukee, Wis.
Manning, C. H., Ogden A.T.S.C., Ogden, Utah
Mansfield, W. A. (Re-election), Conduits & Elec. Raceways, Ltd., Toronto, Ont., Can.
Mason, C. M. (Re-election), Cincinnati & Sub. Bell Tel. Co., Cincinnati, Ohio
Miller, N. A. (Re-election), Sargent & Lundy, Chicago, Ill.
Miller, R. H., Gen. Elec. Co., Des Moines, Iowa
Molenaar, C. R., U.S.E.D., Oak Ridge, Tenn.
Morgan, R. I., A. Reyrolle & Co., Ltd., Durham, England
Nilsen, P. J., P. J. Nilsen Co., Oak Park, Ill.
Norman, R. W., Rural Elect. Adm., St. Louis, Mo.
O'Connor, A. J. (Re-election), Wis. Elec. Pr. Co., Milwaukee, Wis.
Parcinski, H. J. (Re-election), Princeton Univ., Princeton, N. J.
Pettigrew, J. (Re-election), Press Wireless, Inc., New York, N. Y.
Podolsky, L., Sprague Prod. Co., North Adams, Mass.
Santos, P. J., Parsons, Brinckerhoff, Hogan & MacDonald, Caracas, Venez., S. A.
Skeen, J. H., U. S. Rubber Co., New York, N. Y.
Talmadge, P. C., RBM Mfg. Co., Logansport, Ind.
Taylor, R. F., Cons. Engr., Houston, Texas
Veit, A. C., County of Los Angeles, Los Angeles, Calif.
Weiner, A., 2 W. 83rd St., New York, N. Y.
Woollaston, A. E., Johnson & Phillips, Ltd., Charlton, London, England

39 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Anthony, H. H., Robt. H. Anthony Co., Boston, Mass.
Brown, W., United Cinephone Corp., Torrington, Conn.
Davis, P. C. (Re-election), Westinghouse Elec. Corp., Boston, Mass.
Edgerton, A. K., Research Const. Co., Cambridge, Mass.
Gomez, J. E., Gen. Elec. Co., Schenectady, N. Y.
Johnson, C. F., Gen. Elec. Co., Pittsfield, Mass.
Lott, A. L., Airadio, Inc., Stamford, Conn.
Munro, L. M., Doble Engg. Co., Medford Hillside, Mass.
Nerenberg, A. C., Curtiss-Wright Res. Lab., Buffalo, N. Y.
Norton, E. G., Robt. H. Anthony Co., Boston, Mass.
Quenell, A. W., Gen. Elec. Co., Boston, Mass.
Ragan, F. T., Jr., Lieut. (jg) U.S.N.R Portsmouth, N. H.
Van Valkenburg, M. E., Mass. Inst. of Tech., Cambridge, Mass.

2. Middle Eastern

Adams, C. A., Gilbert Associates, Inc., Reading, Pa.
Beiner, R., Philco Radio Corp., Washington, D. C.
Bevan, C. B., Phila. Elec. Co., Chester, Pa.
Buchanan, D. L., Alum. Co. of America, Newark, Ohio
Carmona, V. S., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Caywood, W. P., Carnegie Inst. of Tech., Pittsburgh, Pa.
Cozzarin, V. J., Westinghouse Elec. Corp., Cleveland, Ohio
de Masi, R. R., Chesapeake & Potomac Tel. Co., Washington, D. C.
Eschbach, D. O. (Re-election), Gilbert Associates, Inc., Reading, Pa.
Frederick, J. J., Gilbert Associates, Inc., Reading, Pa.
Gallen, H. R., Phila. Elec. Co., Philadelphia, Pa.
Gates, E. S., Westinghouse Elec. Corp., Sharon, Pa.
Gilkey, G. A., Westinghouse Elec. Corp., Sharon, Pa.
Goodell, L. J., Westinghouse Elec. Corp., Lima, Ohio
Groetzinger, C. A., Leece-Neville Co., Cleveland, Ohio
Haddy, H. P., Phila. Elec. Co., Norristown, Pa.
Hedding, L. K., Union Switch & Sig. Co., Swissvale, Pa.
Hervey, G. H., Leland Elec. Co., Dayton, Ohio
Holden, R. A., Phila. Elec. Co., Philadelphia, Pa.
Howland, R. A., Briggs Clarifier Co., Washington, D. C.
Hughes, K. M., Union Switch & Sig. Co., Swissvale, Pa.
Kane, J. T., U. S. Navy Yard, Philadelphia, Pa.
Krone, N. J., Jr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Mann, A., Reliance Elec. & Engg. Co., Cleveland, Ohio
McDowell, G. R., Westinghouse Elec. Corp., Sharon, Pa.
Myers, R. J., Phila. Elec. Co., Philadelphia, Pa.
Nash, A. R., Phila. Elec. Co., Chester, Pa.
Pflieger, A. B. (Re-election), Dravo Corp., Wilmington, Del.
Shellberg, S. G., Jr., Goodyear Tire & Rubber Co., Akron, Ohio
Spayd, R. S., Gilbert Associates, Inc., Reading, Pa.
Taylor, W., Jr., Phila. Elec. Co., Philadelphia, Pa.
Thacker, H. C., Master Elec. Co., Dayton, Ohio
Trainham, J. S., Phila. Elec. Co., Philadelphia, Pa.
Werne, G. E., Westinghouse Elec. Corp., Sharon, Pa.
Wiegandt, K. M., Pa. Pr. & Lt. Co., Allentown, Pa.
Windshimer, H. W., Jr., Ohio Power Co., Bellaire, Ohio
Wright, H. E., Ensign, U.S.N.R., Washington, D. C.
Younkman, C. C., Amer. Tel. & Tel. Co., Dayton, Ohio

3. New York City

Dryden, J. C., Morganite Brush Co., Inc., Long Island City, N. Y.
Frazer, D. L., Westinghouse Elec. Intl. Co., New York, N. Y.
Hickey, L. J., Ward Leonard Elec. Co., Mount Vernon, N. Y.
Johnson, D. J., Jr., Maritime Switchboard, New York, N. Y.
Koelling, W. C., H. A. Fraser, Inc., New York, N. Y.
Martin, E. O., Westinghouse Elec. Corp., Newark, N. J.
Naybor, E. V., Sperry Gyro. Co., Inc., Great Neck, N. Y.
Perez, E. E., J. A. Tuck, Cons. Engr., New York, N. Y.
Smith, E. J., Lepel High Frequency Labs., New York, N. Y.
Weil, K., Espey Mfg. Co., Inc., New York, N. Y.

4. Southern

Byerley, J. L., J. A. Jones Const. Co., Inc., Knoxville, Tenn.
Eckmann, H. H. (Re-election), Commonwealth & Southern Corp., Birmingham, Ala.
Grayson, F. O., Mfg. Repr., Coral Gables, Fla.
Killingsworth, H. M., Gen. Elec. Co., Miami, Fla.
Legeai, R. F., New Orleans Pub. Serv., Inc., New Orleans, La.
Millican, H. G., O. V. Scott Elec., Atlanta, Ga.
Moreland, H. W., Fraser-Brace Engg. Co., Inc., Camden, Ark.
Newton, R. L., Amer. Tel. & Tel. Co., Richmond, Va.
Roselle, D. T., Southern Bell Tel. & Tel. Co., Miami, Fla.
Sanders, J. L., Jr., Fla. Pr. & Lt. Co., Sarasota, Fla.
Shipley, G. H., Southern Bell Tel. & Tel. Co., Miami, Fla.
Thayer, N. B. (Re-election), City Water & Light Plant, Jonesboro, Ark.
Thompson, L. H., U. S. Engr. Office, Kingsport, Tenn.
Travis, K. L., Clinton Engineer Works, Oak Ridge, Tenn.
Yoerger, E. J., U. S. Navy, New Orleans, La.

5. Great Lakes

Andersson, M. A., Pub. Serv. Co. of Northern Ill., Chicago, Ill.
Bartlett, H. W., Pub. Serv. Co. of Northern Ill., Chicago, Ill.
Beebe, N. R., Line Material Co., Milwaukee, Wis.
Birkey, V. G., Allis-Chalmers Mfg. Co., Minneapolis, Minn.
Borchelt, C. T., R. G. LeTourneau, Inc., Peoria, Ill.
Buehrig, T. F., Morton Elec. Serv. Co., Morton, Ill.
Cooper, R. B., Consumers Pr. Co., Grand Rapids, Mich.
Covington, C. J., Dowzer Elec. Mchy. Works, Mount Vernon, Ill.
Davis, L. J., Pub. Serv. Co. of Northern Ill., Glencoe, Ill.
Dulevich, N. C., Bendix Prod. Dif., South Bend, Ind.
Fogliatti, J. J., Detroit Public Works Dept., Detroit, Mich.
Getz, H. R., Keystone Steel & Wire Co., Peoria, Ill.
Goldstein, M., Amer. Television Labs., Chicago, Ill.
Kuder, R. C., Moe Bros. Mfg. Co., Fort Atkinson, Wis.
Lally, L. A., Gen. Elec. Co., Fort Wayne, Ind.
Levine, D. L., Commonwealth Edison Co., Chicago, Ill.
Lundquist, W. C., Travelers Ins. Co., Peoria, Ill.
Metz, J. (Re-election), Commonwealth Edison Co., Chicago, Ill.
Roof, R. B., Eaton Mfg. Co., Battle Creek, Mich.
Strong, I. W., Allison Div., General Motors Corp., Indianapolis, Ind.
Taylor, G. Y. (Re-election), Pub. Serv. Co. of Northern Ill., Evanston, Ill.
Tindell, N. W., Keystone Steel & Wire Co., Peoria, Ill.
Wasson, L. C., Mil. Gas Spec. Co., Milwaukee, Wis.
Wright, J. L., Jr., Wright Engg. Co., Indianapolis, Ind.

6. North Central

Black, H. A., U. S. Bur. of Reclamation, Denver, Colo.
Brooks, H. A., Pub. Serv. Co. of Colo., Boulder, Colo.

7. South West

Blackstone, L. B., Houston Ltg. & Pr. Co., Houston, Texas
Carter, G. H., Jr., Southwestern Pub. Serv. Co., Amarillo, Texas
Cline, G. W., Brown Shipbldg. Co., Houston, Texas
Hirsch, L. L., Gulf States Util. Co., Port Arthur, Texas
Klepinger, L. H., Curtiss-Wright Corp., St. Louis, Mo.
Lyford, W. T., Southwestern Pub. Serv. Co., Seagraves, Texas
Miller, R. P., Southwestern Pub. Serv. Co., Amarillo, Texas
Ogg, C. B., Amer. Tel. Tel. & Co., Wichita, Kans.
Pace, L. C., Gulf States Util. Co., Beaumont, Texas
Robinson, E. W., Southwestern Pub. Serv. Co., Amarillo, Texas
Rouse, R. N., Gulf States Util. Co., Beaumont, Texas
Shreve, W. P., Gen. Elec. Sup. Corp., Amarillo, Texas
Strom, M. E., Southwestern Pub. Serv. Co., Borger, Texas
Stull, C. V., J. E. Murray & Co., Kansas City, Mo.

8. Pacific

Bagwill, L. E., State Bridge Dept., Sacramento, Calif.
Buzolin, S. S., Marinship Corp., Sausalito, Calif.
Colon, P. R., Jr., Holmes & Narver, Los Angeles, Calif.
Davenport, M. E., Southern Calif. Edison Co., Ltd., Vernon, Calif.
Drescher, E. E., U. S. Naval Drydocks, San Francisco, Calif.
Ernsberger, W. P., 1st Lt., U. S. Army, Fresno, Calif.
Farrell, R. J., Ensign, U.S.N.R., c/o F.P.O., San Francisco, Calif.
Foster, E. M., San Diego Gas & Elec. Co., San Diego, Calif.
Fuller, R. L., Lockheed Aircraft Corp., Burbank, Calif.
Pierce, F. J., Hughes Aircraft Co., Culver City, Calif.
Price, J. P. (Re-election), Gen. Elec. Co., Fresno, Calif.
Shryock, C. S., Columbia Steel Co., Los Angeles, Calif.

9. North West

Beede, C. H., Seattle Lighting Dept., Seattle, Wash.
Brudick, W. E., Portland Gen. Elec. Co., Portland, Oreg.
Elliott, C. H., Alum. Co. of America, Mead, Wash.
Johnson, F. J., Portland Gen. Elec. Co., Portland, Oreg.
Pope, S. J., Alum. Co. of America, Spokane, Wash.

10. Canada

Gregory, E. S., B. C. Elec. Ry. Co., Ltd., Vancouver, B. C., Can.
Hovey, L. M. (Re-election), Winnipeg Elec. Co., Winnipeg, Man., Can.
Mayberry, F. C., Canadian Natl. Exhibition, Toronto, Ont., Can.

Elsewhere

Aspillaga F., L. E., Valparaiso St., Vina del Mar, Chile, S. A.
Frese, R., Jr., Veracruz Elec. Lt., Pr. & Trac., Ltd., Veracruz, Mex.
Humphries, P. W., Standard Tels. & Cables, Wellington, N. Z.
Ray, J. A., U. S. Navy Yard, Pearl Harbor, T. H.

Total to grade of Associate
United States and Canada, 136
Elsewhere, 4

OF CURRENT INTEREST

Edward P. Burch Dies

Edward Parris Burch, retired consulting engineer, Minneapolis, Minn., died May 4, 1945. Mr. Burch was born on August 20, 1870, in Spring Brook, Wis., and was graduated from the University of Minnesota in 1892. Following his graduation he became engineer of power for the Twin City Rapid Transit Company, Minneapolis and St. Paul, Minn., and remained in that position until 1900 when he became a consulting engineer. In the latter capacity, Mr. Burch laid the first high-voltage underground cable installed in the United States (13,000 volts) and, in 1898, had charge of the installation of electric machinery for a 10,000-horsepower-capacity hydraulic plant at St. Anthony's Falls on the Mississippi River. From 1899 until his retirement in 1936, he was active as a consulting engineer throughout the nation, specializing in electric-traction and evaluation problems.

Mr. Burch was a charter member and past chairman of the Minnesota Section of the AIEE of which he was a local member at the time of his death. He was the author of two books, "Electric Traction for Railway Trains" and "Telephone Rates in Detroit."

Foreign Scientists Barred From Practice in Mexico

Foreign members of the scientific professions have been excluded from practicing in Mexico by the provisions of a recent law which sets up standards and conditions of practice for the professions.

A few exceptions have been made on a temporary basis for persons whose services cannot be replaced easily. The only foreigners thus exempt from the law must:

1. Be professors of specialties still not taught or display unquestionable and outstanding competence in the opinion of the General Bureau of Professions.

2. Be consultants or instructors dedicated to the establishment, organization, or installations of institutions of public or military instruction, laboratories, or institutes of essentially scientific character.

3. Be technical directors in the development of the country's natural resources.

WAR PROGRAM • •

Dummy Head Tests Heating Pads for Oxygen Masks

An automatic breathing head which has a wooden skeletal structure and dermis and epidermis layers of synthetic rubber between which hair-thin electric heating wires are wrapped around the forehead and over the nose and cheeks has been developed by the General Electric Company and the Air Technical Service Command, Wright Field, Dayton, Ohio. The head was built to aid in the testing of small close-fitting blankets for oxygen masks worn in substratosphere temperatures. The moisture in the aviator's breath often forms ice inside the mask thus endangering the oxygen supply.

During the testing, the dummy head is placed in a cold chamber and operated from a cabinet in an adjacent room. A cable containing 62 wires connects cabinet and head. The cabinet contains a bellows designed by the Aero Medical Laboratory to operate a heart-shaped cam which gives the pause in the breathing pattern. By changing cam sizes, breathing rates can be changed. A "breathing orifice selector," set in the base of the head gives five choices of inhalation and exhalation rates through the nose or mouth or both. A slight suction is produced in the mouth and nostrils by the control bellows. The regulator responds, and oxygen is fed to the head through the orifice selector and through a tube to an adjustable heater which raises the temperature as in human respiratory passages. On the exhalation stroke, the oxygen is forced from the bellows through a humidifier which feeds it with water. A "dehumidifier heater" in the base of the head makes adjustment of the amount of moisture in the exhaled breath possible.

First attempts at breathing-head construction failed because the fine wires broke down under repeated adjustment of the masks. Finally the straight wire was replaced with spiraled-wire construction, an innovation which will result in greatly improved electrically heated blankets and similar household equipment. This new wire, now used in garments and blankets for the Army Air Forces, has a flexing life more than ten times that of the straight wire formerly used in electric blankets.

Parallel Generator Operation for Bomber Power Systems

Parallel operation of 400-cycle a-c aircraft generators under conditions simulating combat emergencies was demonstrated recently to representatives of the Army Air Forces at the General Electric Company, Schenectady, N. Y. Engineers of the company say that the new parallel arrangement will prevent any of the remotely controlled machine-gun turrets from being knocked out of action owing to loss of an engine. In effect, paralleling permits the airplane's generators to replace one another instantaneously and automatically. Thus, power supply to all of the electrically operated turrets is continuous, even though part of the system is put out of commission.

Parallel operation of the generators required the development of a new high-speed governor capable of holding frequency and dividing the power load equally among engines operating at different speeds. The new governor is described as an electromagnetically actuated pilot valve operating a hydraulic servo mechanism.

Success of the parallel generator operation permits the use of an a-c system throughout the airplane. Problems of commutation and brushwear at high altitudes are minimized with the a-c system.

In the demonstration two 400-cycle 30-kw 40-kva aircraft alternators were used. Each alternator was driven by a 450-horsepower aircraft engine through Sundstrand variable-ratio drives governed to maintain synchronism and equal-load division in spite of imposed variations in engine speed. A special air cap over the exciter end of each alternator provided cooling air for the ground test, substituting for rammed air. A gearbox arrangement was used to simulate the step-up gear for the accessory drive employed on an actual aircraft-engine installation.

Robot Cuts Pilot's Duties

An "automatic engineer" for aircraft powerplants, which combines three engine-control operations into one and simplifies the job of the fighter pilot allowing him more time for fighting, has been announced by the General Electric Company, Schenectady, N. Y. This system used in connection with the turbo-supercharged engine, sets the throttle, engine-speed control, and the manifold-pressure regulator. The automatic engineer is responsible for maintaining constant-power output as the airplane ascends by adjusting the turbocharger which compensates for the greater difficulty of engine operation in rarefied atmospheres. By reducing the human equation a more uniform and efficient performance of the power plant is obtained. At extremely high altitudes or after battle damage the unit also limits the maximum operating speed of the turbosupercharger to a safe value. The amount of linkage and cables otherwise required also is reduced. When necessary during long flights, the pilot may take control and regulate manifold pressure and engine speed separately.

Field-Wire Circuits Strung From Airplane

A method of laying communication wire by airplane originally developed for light combat wire now has been perfected for the heavier standard field wire by Bell Telephone Laboratories, Inc., at the request of the Air Technical Service Command.

It has been demonstrated in tests that the new plastic-insulated wire or the heavier wire which is standard with the American and British Armies can be paid out from a *C*-47 transport airplane at speeds up to 250 feet a second. One or two miles of wire are packed in criss-cross coils which are easily handled and offer the advantage that two layers of wire cannot be started at the same time during the unwinding process. In wire-laying operations the coils are lined up in echelon from the open doorway of the airplane to the forward end of the cargo space, secured to the floor, and the outside end of the first coil is spliced to the inside end of the

Interior of a C-47 transport airplane with field-wire coils ready for trial run

one behind. The inside end of the first coil is led outside the airplane through a pipe six inches in diameter, brought back into the cargo space, and attached to a parachute. The parachute is thrown out to a ground party at the starting point. Eventually the other end of the wire pulls free of the airplane and is picked up by a ground party at the end of the communication line.

Film Depicts Japanese Strategy. Captured Japanese movies, animated maps, and combat pictures are combined in the latest Navy motion picture, "The Admiral's Reply," made available by the Navy's industrial incentive division for war-plant and labor-union showing. Narrated by Rear Admiral DeWitt C. Ramsey, chief of the Navy's Bureau of Aeronautics, the picture presents the enemy as rich in natural resources and man power, fighting a religious war, and planning a delaying action in the hope the Allies will tire of the war. Facts on the size of the Japanese army and air force and on the Japanese soldier's fighting fanaticism are illustrated pictorially.

INDUSTRY • • • • •

FPC Approves Mergers

The Federal Power Commission has approved the merger of the facilities of the Wachusett Electric Company, the Leominster Electric Light and Power Company, and the Middlesex County Electric Company, all of Massachusetts. As a result of the merger, the Wachusett Company will acquire all the operating facilities, own all the assets, and assume all the liabilities of the Leominster and Middlesex companies.

The FPC also has approved the merger of the Worcester Suburban Electric Company, the Milford Electric Light and Power Company, and the Union Light and Power Company, all Massachusetts companies. The Worcester Company will take over the operating facilities, assets, and liabilities of the other two companies. The territories served by these companies are contiguous, and all three purchase their energy requirements from the New England Power Company, an associate company.

Plastic Lens Provide Larger Television Images

With the use of a plastic lens, a television receiver is scheduled for the postwar home which will project an image five times as large as that obtainable with prewar models. The new lens, made from Lucite manufactured by the E. I. Du Pont de Nemours and Company, Inc., can be molded to the required optical curvature within a few minutes. It replaces the expensive glass lens which took days to grind and polish.

The lens is part of a projecting system employing the optical principle of the Schmidt astronomical camera, but, with its adaptation for short-distance projection and the low cost entailed by molding the aspherical correcting lens from clear plastic, it now can be incorporated in a television set for home use. In the application of the astronomical-camera principle for television, the spherical mirror collects light from the image produced on the face of the cathode-ray tube and enlarges it to a 16-by-21-inch picture on the viewing screen. For theater projection images as large as 15 by 20 feet may be produced.

In the model developed by the RCA Victor division of the Radio Corporation of America, the plastic correcting lens has a hole in the center and is placed around the neck of the cathode-ray tube so that the image from the spherical mirror is corrected before it strikes an inclined flat mirror near the top of the receiver cabinet. The picture then is thrown onto a translucent vertical screen mounted in front of the cabinet.

Automatic Plotting Developed

An electrically operated recording densitometer which automatically computes a true logarithmic graph of its findings has been developed for use in any investigation where variations in the subject can be detected by electronics. It is of particular value for the detection of variations in photographic or radiographic film. The instrument completes in 30 seconds a permanent curve that formerly required a number of individual hand operations. Thus, not only is much labor saved, but a more accurate graphical representation of the data is made possible. The densitometer was designed and built by the Western Electric Company and the Leeds and Northrup Company for Triplett and Barton, Inc., Burbank, Calif.

Canadian Radio Market Estimated. An immediate market for only 135,000 home radio sets was estimated from a survey recently conducted by Canadian Facts, Ltd., for the Radio Manufacturers Association of Canada. Of these 65 per cent would be a-c models, 20 per cent combination models, and 15 per cent battery sets. Although 42 per cent of the persons interviewed plan to buy a new set after the war, only five per cent will buy sets as soon as they are available. Other facts revealed by the survey were:

Nine out of ten families now own a radio set, and one out of ten has more than one radio.

Five per cent of all sets now owned are out of order.

Radios rank after automobiles and refrigerators on the Canadian family's list of prospective purchases.

Combination sets elicit the most interest with tone the first consideration and price second.

Only one person in ten has heard of frequency modulation.

New Windings for Motors. A three-horsepower winding for a $1^1/_2$-horsepower frame has been designed which will permit drill-press motors to withstand constant overloading, often in excess of five horsepower, without failure. According to L. G. Young, shop superintendent of the Arthur H. Wagner Company, Chicago, Ill., designers of the winding, the use of Fiberglas insulation throughout the rewound motors enables them to withstand the high temperatures induced by constant overloading. The motors formerly used were $1^1/_2$ horsepower cotton-insulated.

Eye-Protection Program Initiated. A research program intended to provide information to be used in combating the many thousand eye injuries that occur annually in American industry has been initiated at Battelle Institute, Columbus, Ohio, under the sponsorship of the American Society of Safety gineers, engineering section of the National fety Council. The investigation, both boratory and statistical, will apply parularly to the evaluation of the performance quirements and specifications of satisfactory astic eye protectors.

ublicity for Patentees' Licensing. A gister of patents available for licensing has en established in the United States Patent ffice, and regular lists of such patents will published in the *Official Gazette of the tent Office*. The purpose of the new service, itiated by the Patent Office at the direction Secretary of Commerce Henry Wallace, to bring to national attention patents under hich the owners are willing to grant licenses. is hoped that such information will lead to eater employment opportunities during conversion.

uare D Plant for Mexico. Formation Square D de Mexico for the manufacture electric distributing and control equipent for the Mexican market is in process of mpletion, F. W. Magin, president, the quare D Company, Detroit, Mich., anounced recently. Square D de Mexico will owned jointly by the United States comany and Mexican industrialists who are perienced in Mexican electrical requireents, Mr. Magin said, and the plant will built in Mexico City, Federal District, soon as arrangements can be completed.

ide Rule for Resistance, Capacitance. parallel-resistance and series-capacitance lculator, a slide-rule device designed to rovide a rapid and accurate means of dermining the reciprocal of the sum of two eciprocals, has been released by the Allied adio Corporation, Chicago, Ill. This calcutor indicates in one setting the numerous airs of resistances which may be connected in arallel, or capacitances in series, to provide ny required resistance or capacitance value. he capacitance and resistance figures on the ce of the rule also can represent inductance, npedance, reactance, or other units which an be handled in a similar manner.

elevision Station Planned. An experiental television station, W2XDK, is schedled for construction by the Sherron Elecronics Company, Brooklyn, N. Y., following e recent granting of a permit by the Federal ommunications Commission.

ilm Pictures Distortion in Welding. motion picture in sound and color, "Preention and Control of Distortion in Arc elding," has been made available to chools, colleges, technical societies, factories, hipyards, and industrial groups by the incoln Electric Company, Cleveland, Ohio. he film, produced by the Walt Disney roductions, prescribes three simple rules for hwarting "Mr. Shrink":

Reduce the effective shrinking force.
Make shrinkage forces work to minimize distortion.
Balance shrinkage forces with other forces.

POSTWAR • • • • • •

Bretton Woods Benefits Electronics Industry, Says Committee

Because the electronics industry underwent a tremendous expansion between 1941 and the present, it will be subject to special reconversion difficulties and will profit particularly from the stabilizing effect of the Bretton Woods agreements, according to a recent report on the "Electronics Industry and Bretton Woods," issued by the Business and Industry Committee for Bretton Woods of which Ralph E. Flanders of the Jones and Lamson Machine Company is chairman. Competitive pressures from within and without will be lessened by the operation of the International Monetary Fund and the International Bank for Reconstruction and Development which were proposed at Bretton Woods, the committee states. The enormity of the electronics industry's problem is reflected in the rise in the dollar value of its output which was $300,000,000 from 1939 to 1941 and is $4,600,000,000 at present.

In analyzing the precarious position of the electronics industry, the report points out that the electronics industry must sell to a consuming and industrial public which is uninformed and unprepared. The industry itself is uncertain about the peacetime use of its products, many of which are strictly military products with only five per cent directly applicable to peacetime needs. Industry sources are quoted as expecting postwar production to equal only $800,000,000 to $1,000,000,000. The prospect of achieving an inevitable contraction on an orderly basis is complicated by the fact that 1,200 firms now have mushroomed from the 400 to 500 operating before the war. Furthermore, the industry's external competitive position will be injured by the fact that the war demand for electronics equipment will be maintained for some time after other industries have begun reconversion. This means electronics will be a tardy competitor for the peacetime dollar.

The electronics industry stands to gain directly in any expansion of foreign markets for United States exports effected by the proposed Fund and Bank, as well as from the stable domestic market accompanying the general prosperity stimulated by expanded foreign trade, the report declares. In the committee's opinion foreign markets offer an important area for electronics sales even in the immediate postwar period, and it is now expected that improved models will be available for export sooner than the models designed for the domestic market. Many of the Latin American countries are ripe for the development of their radio markets. A recent study of the situation in Argentina by the Department of Commerce reported very favorably on potential consumption of radio equipment and parts from the United States. The industrial development which will be undertaken by these countries, and the reconstruction projects of Europe and Asia also will create what should be an important market for the electronics industry. It will be much easier to sell electronics equipment when new investment for reconstruction and reconversion must be undertaken, than it will be to induce firms to replace expensive equipment at a later time. These early purchases, moreover, will establish the replacement and maintenance market for many years to come.

How quickly new devices will be introduced, the report designates as the most important question for the future of the industry. The wartime growth of knowledge and experience in electronics will help, but the full potentialities of the market can be realized only in a prosperous and expanding economy. American industry will replace existing machinery with new electronic equipment, only if the market for its products is growing. A sharp industrial contraction will reduce the interest of American business in new and expensive electronics products. Similarly, electronics can speed up and cheapen the production of airplanes, helicopters, and prefabricated houses for consumers, but the demand for these products can be created only by jobs and prosperity, the committee warns.

In the immediate postwar years, prosperity in the United States will depend in part on the expansion of its foreign markets and the revival of world trade. Foreign countries are anxious to buy commodities, but without financial assistance they will be unable to do so. The International Bank and Fund will provide the necessary assistance by making it possible for countries to achieve a better balance in their international payments position and by working to remove the restrictive monetary policies which curtailed world trade in the past. The International Bank also will assist European countries to obtain special credits for the reconstruction and development job which must be done. It will help them to buy electronics equipment directly, and it will help them to buy the iron and steel and prefabricated houses which will create a demand for electronics equipment within the United States, according to the committee's summary.

College Presidents Polled on Universal Military Training

A survey of the reactions of college and university administrators and professors to universal military training has revealed that about one half of those questioned are against the institution of such a program. This conclusion is the result of 1,196 replies to a questionnaire prepared by the American Council on Education, the American Association of Junior Colleges, and the American Association of University Professors, and sent by the former two organizations to 1,685 college, university, and junior-college presidents.

Of those questioned, 77.1 per cent believed that the decision regarding the establishment of peacetime military training for the United States should be deferred until the establishment of peace. Replies also indicated that 80.1 per cent favored the creation of a national commission representative of many interests—Army and Navy, education, business, labor, agriculture, and religion—to study all aspects of postwar military training and to make recommendations to Congress. However, 47 per cent of the questionnaire recipients definitely were opposed to the establishment of universal military training as a peacetime policy, as compared with 38.3 per cent who were in favor of it. The others were uncertain or would not commit themselves.

Railroad Abandons Steam for Diesel Locomotives

A postwar conversion from steam to Diesel-electric locomotives will be started immediately by the New York, Ontario, and Western Railway, according to Raymond L. Gebhardt and Ferdinand J. Sieghardt, trustees. It is estimated that complete replacement of steam by Diesel-electric power would result in operating economies of $1,000,000 a year.

The New York, Ontario, and Western Railway has about 550 miles of main line, much of it with many curves and steep grades, and it is under these conditions that Diesel-electric power operates at the greatest advantage compared with steam. Abandonment of unprofitable branch lines and conversion of 110 miles of double-track main line to single track also are expected to contribute to the anticipated saving.

OTHER SOCIETIES •

ASME Holds Aviation Conference. New aircraft techniques and a projection of postwar plans for the industry were the business of the 16 sessions which comprised the Aviation War Conference of the American Society of Mechanical Engineers held at the University of California, Los Angeles, June 11–14. The four-day conference was under the auspices of the Southern California section of the society, and attendance of persons requiring train or hotel reservations was discouraged. Among the speakers scheduled for the opening session were: Clarence A. Dykstra, provost of the University of California; M. J. Zucrow, executive engineer, Aeroject Engineering Corporation, Azusa, Calif., whose topic was "Jet-Propulsion Principles and Rockets for Assisted Take-Off"; and Colonel Homer Boushey, Bakersfield (Calif.) Army Air Field, who discussed "Jet-Propelled Airplanes." In all, 38 papers were presented during the conference.

Meeting of the American Physical Society. The 266th meeting of the American Physical Society was held at Ohio State University, Columbus, June 15–16, 1945, with limited attendance. The second annual meeting of the society's division of electron and ion optics, and a group of invited papers on biophysics were included in the program. Sessions on spectroscopy and nuclear physics also were held. Priority of attendance was given to authors of papers by the society, which made reservations for only 50 members not from the local commuting zone.

George Seabury Dies; William N. Carey Succeeds Him

George T. Seabury, secretary of the American Society of Civil Engineers since 1925, whose retirement would have become effective June 1, died May 25, 1945. It was under his direction that the ASCE membership grew from about 11,000 to nearly 21,000 and *Civil Engineering*, which featured reports on works in progress in a more popular vein, was established as a monthly publication.

At the beginning of the century Mr. Seabury, who was graduated from the Massachusetts Institute of Technology in 1902, worked on the Catskill water supply for the City of New York and on the water supply for Providence, R. I. During World War I he served as major in the United States Quartermaster Corps and afterwards formed his own company to engage in general construction work. Before his death Mr. Seabury had accepted an appointment as assistant to the president of the ASCE, a new post.

Colonel William N. Carey, former consulting engineer of St. Paul, Minn., recently on active duty as chief engineer of the Federal Works Agency, has been named new secretary of the ASCE. A native of St. Paul, Colonel Carey attended the University of Minnesota. He served on the Western Front as a major in the Corps of Engineers in World War I. During the present war he served for a year in the Jacksonville, Fla., United States Engineer District in charge of design of Army airdromes and camps. In 1942 he was transferred to the FWA in Washington, D. C., as chief engineer. Between wars Colonel Carey was occupied variously as partner in a consulting engineering firm, city engineer of St. Paul, and state engineer for the Public Works Administration. He supervised for the Government the design and construction of the $17,000,000 sewerage and sewage-treatment project of the Minneapolis–St. Paul Sanitary District. He has been an ASCE member since 1916 and has held several society offices.

RESEARCH • • • • •

New Laboratory Designed by General Electric Company

Erection of a new $8,000,000 building for the General Electric Company's research laboratory, which will afford some 50 per cent more space than present facilities, has been announced by Charles E. Wilson, president of the company.

As planned the new laboratory anticipates the immediate postwar expansion of the staff from about 540 to 800 persons, and the probable needs of the next 15 or 20 years. Provision has been made for space to build special-purpose structures, as well as for a central building with ample grounds for additions on a 219-acre estate in Niskayuna, near Schenectady, N. Y.

The new building will be T-shaped and will vary from two to five stories in height with 200,000 square feet of laboratory working space, an auditorium seating 300, a dining room, and conference rooms. One third of the laboratory space will be devoted to service facilities, machine shops, and specialty shops. Walls between rooms will be movable, capable of being placed at 18-inch intervals, so that rooms may be made larger or smaller. Benches and furnishings will be standardized, so that they can be shifted from place to place. The building will be air-conditioned throughout, and wires and pipes carrying various voltages of electricity, compressed-air suction, illuminating gas, hydrogen, and oxygen will be so placed that they can be brought into any room.

JOINT ACTIVITIES

Bureau of Standards Issues Lightning Handbook

Handbook *H*40, illustrated latest edition of the *Code for Protection against Lightning*, has been issued by the National Bureau of Standards, United States Department of Commerce. The Lightning Code is sponsored by the Bureau of Standards in co-operation with the AIEE under the procedures of the American Standards Association.

Part 1 of Handbook *H*40 deals with the protection of persons, while part 2 concerns the protection of buildings and sets up standards for adequate rodding of such structures. The third part of the publication covers structures containing flammable liquids. Because of developments during the past seven years, this portion of the code has been revised by a representative committee headed by W. W. Lewis (F '38) of the General Electric Company, Schenectady, N. Y., and now contains a number of modern methods for protecting oil refineries, tank farms, and the like. Copies may be purchased for 20 cents each from the Superintendent of Documents, Washington 25, D. C.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Edwards Perpetual Calendar

To the Editor:

A member of the AIEE and also a member of the World Calendar Association wrote us a letter relating to an article appearing in the April 1945 issue of *Electrical Engineering* which dealt entirely with the proposed Edwards Perpetual Calendar. The writer suggested that the editor should give equal space to the World Calendar of 12 months and equal quarters, which is every year the same and which begins every year with Sunday, the first day of the week.

For the information of your readers I should like to mention certain facts in connection with the proposed Edwards Perpetual Calendar.

In arrangement it is identical to the one by Professor L. A. Grosclaude that was published in Switzerland in March 1900. This plan was definitely rejected by the official Swiss Committee on Calendar Reform. The plan, now known as the World Calendar, received official recognition by the Swiss Government in June 1931.

The great drawback of the Grosclaude Calendar was the beginning of the year on a Monday, and designating Monday as the first day of the week, which is contrary to history and custom. And this same drawback also appears in the Edwards Calendar.

In 1937 the League of Nations submitted to its member and nonmember States the Chilean draft resolution for the World Calendar and thereby eliminated all the other previously submitted plans.

The perpetual World Calendar of 12 months and equal quarters has received the approval of 14 nations (Afghanistan, Brazil, Chile, China, Estonia, Greece, Hungary, Mexico, Norway, Panama, Peru, Spain, Turkey, and Uruguay). Many organizations have endorsed it among them—the Chicago Association, New York State, Pittsburgh, and St. Louis Chambers of Commerce, and the London, British, and Empire Chambers of Commerce. *Influential scientists*, mentioning but a few are—Robert A. Millikan, Sir H. Spencer-Jones, and Harlan T. Stetson; *educators*—John Dewey, Dugald C. Jackson, William Allan Neilson; *leading men and women*—James Truslow Adams, Carrie Chapman Catt, Ira A. Hirschmann, Isadore Lubin, Minnie L. Maffett, Helen McKinstry, Julius F. Stone, Gerard Swope, Mary E. Woolley.

Let me quote from Commodore J. F. Hellweg, United States Navy retired, superintendent of the United States Naval Observatory in Washington, D. C.:

> "My advice to all advocates of calendar revision is to devote their energies to the only proposal which meets all the requirements of the situation with a minimum of upheaval and disturbance and a maximum of benefits to mankind—the world calendar."

ELISABETH ACHELIS

(President, World Calendar Association, New York, N. Y.)

To the Editor:

The World Calendar was rejected by the League of Nations in 1931, and, after the World Calendar Association and its members again promoted its reconsideration in 1937, the draft was submitted to all member and nonmember States by the League. Forty-five replies were received of which only 14 accepted the draft. The others politely rejected it or made no observations, the United States was noncommittal, the Vatican remained aloof, and the League of Nations definitely put the World Calendar aside.

Of previous endorsers of the World Calendar Sir H. Spencer-Jones, the Astronomer Royal, regards a plan similar to mine (30, 30, 31 day months and the year, the quarter, and the week starting on a Monday) as "probably the simplest and with the most to recommend it." The statement by Captain J. F. Hellweg was made in 1933, before the Edwards Calendar was publicized.

My plan has not been rejected and is not identical to any other previously rejected plan. The Swiss claim no monopoly on calendar revision, nor do they have nor claim any authority to lead the world on this subject. From my study of calendar history I find that hundreds of new calendars have been proposed in the past. Two of these are similar to the Perpetual Calendar but are not identical. The Grosclaude plan began the year with Monday, January 1, had a "leap day" in the middle of the year, and an annual "blank day" for the 365th day. Another and earlier plan began the year on Monday, January 1, had an annual "blank day" in the middle of the year, and a "leap day" at the end of the year. The Edwards Perpetual Calendar begins the year on a "second Sunday," which is New Year's Day, and Monday, January 1, is the second day of the year. Leap Year Day is the first day of the second half year in leap years, and the 365th day is December 31, as at present.

These differences are really important ones inasmuch as they are some of the reasons why the Perpetual Calendar is considered practical, simple, and up-to-date, whereas other proposals have been rejected as being impractical and confusing.

The first day of the year, New Year's Day an already well-known holiday, as an international civil holiday in the business world, is the most logical day to consider as a day apart. Then 364 days, evenly divisible into equal quarters and whole weeks, follow without any confusing "blank day," December *Y* December *W*, Year End Day, or a "Sylvester" at the end of the year. The Edwards Perpetual Calender year will end normally with December 31, as at present.

Leap Year Day as the 184th day in leap years is the most logical place for this "day apart" also. It will provide a summer holiday for the vast majority of the world's population, and, as the first day of the second half year, it will balance New Year's Day exactly for comparison purposes.

The 30, 30, 31 day arrangement is most practical, since it not only allows the quarter months to start on the significant and easily remembered business days of Monday, Wednesday, and Friday, but also allows the 91st day of each quarter to fall on a most appropriate day for quarter-end accounting. Since this civil calendar is proposed primarily for world-wide business reasons, this arrangement is most logical.

As for the week beginning on Monday, this has been the *custom* for many years and is the reason why so many calendars have been proposed this way. Saturday and Sunday long have been known and considered as the weekend. Many minds have thought it would be honest so to show it on the calendar, and many calendars, diaries, and account books have been printed with Sunday as the seventh day of the week. The majority of schools, colleges, and business institutions consider Monday as the first day of the week, and the majority of clergymen think of their Sunday sermons and services as concluding a week's work of preparation. Monday begins a new work week for them. Only a few people have objected to showing Monday on the calendar as the first day of the week, and Sunday as the seventh.

It makes no difference whether worship is held on a day called Saturday or Sunday or any other name. As one editor so ably put it:

> "The calendar is simply an invention of man. It was not created by any higher being, and it is no more sacred than the practice of dividing each day into twenty-four hours."

Nearly all the individual days of the week are sacred to some man-devised method of religious observance. There are hundreds of various religions, possibly thousands, and it would be utterly impossible to devise a religious calendar that would satisfy half of them.

The Perpetual Calendar is proposed as a practical up-to-date civil calendar, based on present day facts and customs. It is a simple sensible method of accounting for our days and for the vast work of the world. It has none of the monotony and indivisibility of the 13-month plan, it is free from the bogey of Friday the 13th, and it has 26 work days, plus sabbaths, in every month of the year. It would benefit both industry and labor, and all that is needed is to overcome human inertia and continually to request the adoption of the Perpetual Calendar until we have it.

W. E. EDWARDS

(Lieutenant, United States Naval Reserve, Radar Maintenance School, Navy Yard 128, c/o F.P.O., San Francisco, Calif.)

State of the Art of Circuit-Breaker Application

To the Editor:

Adequate circuit-breaker application has lagged in many fields, particularly for industrial use. It often has been difficult to convince the holders of the purse strings of the value of sound electrical practice. There is evidence, however, that industrial management is awakening to the importance of this subject. The situation potentially presents a huge backlog of business to the circuit-breaker manufacturers. It is unfortunate, therefore, that there should be certain trends in the design and application of circuit breakers which will place an unnecessary burden on many users and may stifle this new interest in better electric equipment.

These trends are exhibited in an emphasis on fast circuit-breaker operation, and application on the basis of interrupting rating, with the mechanical (short-time) rating playing a subordinate role. This is satisfactory for central-station practice, particularly in the case of the larger circuit breakers. But in the industrial field, and even for many utility installations, blind subservience to this policy often results in the use of much larger and more expensive circuit breakers than necessary. An intelligent application of available circuit breakers often will effect substantial savings, whereas certain changes in design would make further economics possible. Suitable talent for adequate analysis often is not available to the industrial user within his own personnel, and he does not always consider himself justified in employing outside consulting service.

Fast circuit-breaker operation is not a universal necessity. Sometimes it is undesirable. The mechanical rating then becomes the important factor and may be the dominating one. Under these circumstances a wide spread between the ampere values for the mechanical rating and the maximum interrupting rating is desirable for optimum circuit-breaker application. But for most power circuit breakers (for use above 600 volts) now on the market the ratio between these two ratings is in the range of only about 1.6 to 1, whereas for the 600-volt class air circuit breakers it is only one to one. The latest National Electrical Manufacturers Association recommendations on circuit-breaker application, now endorsed by certain leading manufacturers, completely disregard these possibilities. These recommendations are undoubtedly an attempt to simplify application procedure, but it is believed that they obscure important features and reduce the procedure to a rule-of-thumb process. Certainly they do not guide the prospective industrial user without a fully staffed electrical department to a more favorable analysis of his problem.

In the power circuit-breaker field, medium voltages of about 2,300 volts are common for service and plant distribution purposes in a wide range of sizes of industrial plants. These cases often involve large concentrations of power from utility sources or their own generating equipment. In plants of this kind co-ordination of circuit-breaker operation usually requires timing sequences which bear no strict relation to interrupting ratings, with the larger and more expensive circuit breakers carrying the longer timings. These timing sequences need not interfere with circuit-breaker co-ordination in the utility system, because modern relay practices permit of sectionalizing to such an extent that full protection can be accomplished practically independent of external faults. Furthermore, many utility systems are so large that faults beyond customer services frequently are felt as only slight overloads.

On the users' premises, then, full latitude should be possible in these cases for an economical application of circuit breakers. But no matter how the designer tries to take advantage of reduced interrupting duties by means of his timing sequence, the mechanical rating of the circuit breaker interposes an insurmountable obstacle. Plants with large connected-motor loads present unusually severe cases. There is a notable gap in available circuit breakers for this range of service. The line of both air and oil circuit breakers reasonably suited for industrial use stops at about 37,000 amperes for the interrupting rating and about 60,000 amperes for the mechanical rating. If either requirement is above these limits, it is necessary to use a much more expensive circuit breaker or to install fault-limiting equipment. Either choice represents an expense. It is obvious that with a higher mechanical rating the smaller circuit breakers could be used more nearly up to their interrupting rating. A ratio of three to one or even higher between the mechanical and maximum interrupting ratings would be most helpful.

In the case of air circuit breakers for use on 600 volts and below, the situation is similar but of a somewhat different nature. These circuit breakers are applied widely close to power consuming machinery, where fast operation is desirable. Some plants require a large number of these circuit breakers of small individual continuous current rating. In the interest of economy circuit breakers of reasonably small size are dictated. But the short-circuit duty is often above the rating of these circuit breakers. To meet this situation the expedient of cascading is utilized, by which a circuit breaker of larger interrupting capacity backs up a group of smaller circuit breakers and opens the circuit after one of the latter has begun to open the circuit but before it has cleared the arc. But cascading is only a makeshift and places the manufacturer in the position of recommending the use of his equipment beyond its rating. For it is to be noted that the short-time (mechanical) ratings of these circuit breakers are identical with the interrupting ratings. Therefore, wherever these circuit breakers must be backed up for interrupting duty, they are being applied beyond their mechanical rating. A ratio of about two to one or three to one between the mechanical and interrupting ratings of these circuit breakers seems to be indicated, or the mechanical rating should be equal to the interrupting rating of the next or second larger size circuit breaker.

It is proposed that the manufacturers initiate a program of increased mechanical ratings for circuit breakers of small and medium size. Some immediate relief may be possible by a rerating of existing designs. Beyond this, it might be asking a large order, involving increased cost of some circuit breakers. But it seems a worth-while cause if smaller circuit breakers can be used. The past emphasis has been on improved interrupting performance, and the designers have done an excellent job in that regard. Here is a new challenge to them.

WILLIAM A. TRIPP

(Electrical engineer, Charles T. Main, Inc., Boston Mass.)

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

ASTM Standards 1944 Including Tentative Standards (a triennial publication). Part 1, Metals, 2,047 pages; part 2, Nonmetallic Materials—Constructional, 1,649 pages; part 3, Nonmetallic Materials—General, 2,202 pages. American Society for Testing Materials, 260 South Broad Street, Philadelphia, Pa., 1944–45. Illustrated, $9^1/_4$ by 6 inches, cloth, $10 per volume. (ESL.)

This new edition of ASTM Standards contains 1,235 specifications and standard methods, including both formal and tentative ones. It also includes the emergency standards and alternate provisions adopted because of wartime conditions. The work appears in three volumes. Each part has an index and may be purchased separately.

Builders of the Bridge. By D. B. Steinman. Harcourt, Brace and Company, New York, N. Y., 1945. 457 pages, illustrated, $8^1/_4$ by $5^1/_4$ inches, cloth, $3.50. (ESL.)

This interesting contribution to the history of bridge building covers the careers of two great engineers of the 19th century. Emigrating to America in 1831, the elder Roebling soon began his engineering life as a railroad surveyor. This was followed by the manufacture of wire rope, for the first time in America. Soon, however, he turned to suspension bridges, the field in which he and his son became famous. Doctor Steinman describes the bridges built at Pittsburgh, Niagara, and Cincinnati, and finally the construction of the Brooklyn Bridge. This last is dealt with in detail. The story is a dramatic one, of interest to laymen as well as engineers.

New Architecture and City Planning. A symposium edited by P. Zucker. Philosophical Library, 15 East 40th Street, New York, N. Y., 1944. 694 pages, illustrated, 9 by 6 inches, cloth, $10. (ESL.)

This symposium represents realistic suggestions for the future of architecture and city planning by leading American authorities. The several sections deal, respectively, with specific building types, new materials and new construction methods, housing, city and regional planning, monumentality in architecture, and the education of citizen interest in the foregoing topics. The social requirements and implications of the various problems are brought out as well as the purely technical aspects.

Photomicrography. 14th edition. Eastman Kodak Company, Rochester, N. Y. 1944. 174 pages, illustrated, $8^3/_4$ by $5^3/$ inches, cloth, $2. (ESL.)

Beginning with description of the necessary apparatus and general optical principles, this small book surveys the process of photography through a microscope in considerable detail. The special techniques for motion photomicrography and color photomicrography are explained, and a selected bibliography is appended.

PAMPHLETS • • • •

The following recently issued pamphlets may b of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuer

Resin Coatings Baked by Induction Heating. By A. P. Mazzucchelli, R. E. Nicolson Bakelite Corporation, 30 East 42d Street New York 17, N. Y., 10 pages.

Industrial Property Records for Accounting and Valuation Uses. C. V. Armstrong Iowa Engineering Experiment Station, Ames Iowa, 96 pages, no charge.

Erie Railroad—Its Beginnings. By Rober E. Woodruff. The Newcomen Society o England, American Branch, New York, N. Y 24 pages.

A Story of Private Industry That Shoul Be Told. By Tom P. Walker. *Public Utiliti Fortnightly*, Washington, D. C., 11 pages.

National Apprenticeship and Trainin Standards for the Electrical Industry Bureau of Training, War Manpower Commission, Washington, D. C., 32 pages.

Induction Heating—A History of Its Development. By Frank T. Chesnut. Aja Electrothermic Corporation, Trenton 5 N. J.

TRANSACTIONS SECTION

Preprint of Corresponding Pages From the Current Annual AIEE Transactions Volume

Statistical Methods Applied to Insulator Development and Manufacture

J. J. TAYLOR
ASSOCIATE AIEE

Synopsis: The science of statistics is highly developed and applicable to a variety of engineering subjects. There remains the task of getting statistical methods out of books and into general use. Towards this end examples are given of problems that relate to high-voltage-insulator manufacture and for which statistical treatment seems desirable.

IN THE MANUFACTURE of high-voltage insulators almost every incentive for statistical analysis is present. The product is produced in large quantity and to meet an exacting service. Product characteristics are determined by tests carried to destruction. Manufacturing control is difficult, because insulators are made in part from natural clays and are processed through incomplete chemical reactions. In service the finished product is exposed to all the vagaries of weather in almost every climate, and is expected to endure for a length of time far beyond a reasonable proof-test interval.

It is apparent, therefore, that the element of chance will be present at every stage of product use and manufacture. To deal effectively with the electrical and mechanical problems of the insulator industry the usual engineering conceptions shown in Figures 1A and 1B should be supplemented by an equivalent group of statistical tools and diagrams.

Statistical Distributions

Many product characteristics that are measured, studied, and specified show a relation between observed values and the frequency with which they occur. If observations are grouped as shown in Figure 2, the distribution is called "normal" and is defined by the value of the arithmetic mean, $\overline{X}$, and by the standard deviation. The standard deviation, σ, is a measure of variability and is the root-mean-square of all the deviations of the individual values from the mean value. It is analogous therefore to the rms value of alternating current.

To carry this analogy further, a sine wave is more often approximated than realized and so also is a "normal" curve. Where the departure is slight, an assumption of normality may introduce no intolerable error and permits the use of many published tables. Nonnormality in a product characteristic does not prove any deficiency in either the product or its control. In some instances, however, direct physical reasons for nonnormal distributions exist and can be ascertained.

In 1934 an excellent statistical manual published by American Society for Testing Materials[1] served as an incentive for the statistical study of a variety of suspension insulators. Frequency diagrams of ultimate-strength tests were plotted from data accumulated in the years preceding. Of the insulator types studied, two were found with distribution curves that proved later to be of particular interest. They are illustrated in Figure 3. A normal curve superimposed on distribution *A* indicates considerable flatness distortion or kurtosis. Distribution *B* is decidedly skewed, with less variability than would be expected in the upper range of observed values.

In both cases a direct physical cause was found for these abnormalities. The flatness of curve *A* resulted from a change in the firing cycle of the porcelain component. Figure 4[7] shows, in an exaggerated manner, how a shift in the average value of test groups produces a flat-top shape when all observations are plotted together.

The abnormality of Figure 3B was caused by a peculiarity of design and requires for its explanation a brief review of insulator construction. A suspension insulator has internal and external metal parts attached with Portland cement to a ceramic shape. In tests of ultimate strength the fracture occurs usually through the ceramic component—a not surprising result since ceramic materials fail at a unit deformation of about 0.1 per cent. The comparable figure for malleable cast iron is 200 times as great. In a design in which the metal sections and the cement matrix areas are liberal, the cement and metal respond under load in accordance with their respective elastic moduli. As a general rule, the elastic modulus of structural materials is exceptionally reliable and consistent; the ultimate strength is variable. One would expect to find, therefore, that the variability of an insulator assembly is determined largely by the variability in ultimate strength of its ceramic component, rather than by erratic performance of the metal parts or cement matrix. The skewness of Figure 3B was attributable to a cap section so thin that its yield point was reached in the upper range of observations. This yield prevented normal support of the ceramic section and development of the potential strength of the strongest ceramic components.

Similar nonnormal distributions to which a physical cause can be assigned are found in high-voltage measurements. Two of these are illustrated in Figure 5. In the parallel arrangement of insulator and sphere gap, a marked lack of symmetry is noticeable in the distribution of

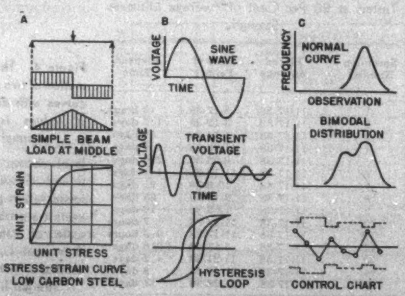

Figure 1. Diagrams of mechanical, electrical, and statistical performance

A. Mechanical
B. Electrical
C. Statistical

Paper 45-89, recommended by the AIEE subcommittee on applications of statistical methods of the Standards committee for publication in AIEE Transactions. Manuscript submitted November 20, 1944; made available for printing March 8, 1945.

J. J. Taylor is chief engineer, insulator division, Ohio Brass Company, Barberton, Ohio.

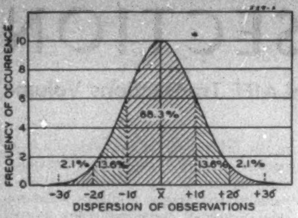

Figure 2. Significant areas and limits of a normal distribution

measurements. The consistent flashover value of the sphere gap cuts off the maximum end of the insulator-flashover distribution pattern.

The opposite type of skewness was observed in tests of imperfect spheres. A sharp projection on the grounded sphere introduced a discontinuity in the otherwise uniform electrostatic field. Flashover could occur from sphere to sphere or sphere to point. In the distribution shown conditions were such that the majority of the flashovers were between sphere and point.

Control of Product Quality

Since a great variety of insulator designs start from a common source of raw materials and go through essentially the same manufacturing process, a measure of quality control can be assured by observations on a few important types. The distribution for one such key insulator is shown in Figure 6. This type of insulator is manufactured in large quantity and, fortunately, has a frequency distribution approximately normal. The design was first produced in 1933. Control limits were not set up until 1937 and were then readily established by a study of accumulated test data.

Daily tests are made on units selected at random from current production and on factory rejects with imperfections that do not influence the characteristic being observed. As shown in Figure 7, the control limits are adjusted for variations in sample size. Sample averages falling beyond the control limits indicate an assignable cause of variation and are a signal for technical inquiry and corrective action.

Table I. Endurance Test of Suspension Insulators

Tested at 80 Per Cent of Average Ultimate Strength

Specimen Number	Placed on Test	Date of Failure	Elapsed Time
1	11-17-38	11-17-38	10 hours
2	11-17-38	3-12-39	115 days
3	11-17-38	1-14-39	58 days
4	11-17-38	11-22-38	5.1 days
5	11-17-38	8-23-39	279 days
6	11-17-38	11-18-38	1.1 days
7	11-17-38	12-8-38	21 days
8	11-17-38	2-13-39	88 days
9	11-17-38	12-3-38	16 days
10	11-17-38	11-17-38	7 hours
11	11-17-38	11-17-38	0.5 hours
12	11-17-38	3-17-42	1,216 days
13	11-17-38	11-21-38	4.2 days
14	11-17-38	11-25-38	8 days
15	11-17-38	11-28-38	11 days

Quality Control in Relation to Routine Tests

Ceramic parts may be inspected visually, sometimes with the aid of penetrating fluids, or aurally by "ringing-out" methods. Attention has been given also to X-ray examination and to nondestructive tests employing supersonic response. Many tests, however, are potentially destructive and would produce failure if increased sufficiently in severity. Dielectric soundness is checked by high frequency or 60-cycle flashover on ceramic parts and assembled units. For certain specialized types of insulators, impulse tests are routine procedure. Routine mechanical tests of assemblies are made at a load level about half the rated ultimate strength and are followed by a dielectric test.

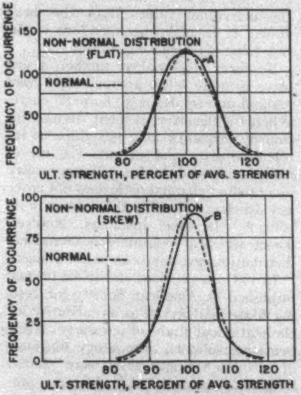

Figure 3. Nonnormal distributions of suspension-insulator strength

As routine tests for both dielectric and mechanical strength are potentially destructive, some compromise is necessary between tests too mild to eliminate defectives and those severe enough to damage an appreciable portion of specimens near the minimum end of the distribution pattern.

Mechanical tests at half the rated strength are not intended to cut off the minimum end of the distribution curve. They are used to give assurance against defectives with potential characteristics far below the minimum level of expectancy.

It cannot safely be assumed that high levels of routine test guarantee quality. Such tests may be particularly undesirable on a product manufactured with good factory control but with no great margin in average strength. In Figure 8 two distribution curves are shown that have the same probability of failure at or below the specified minimum level. If both groups of product are proof-tested to eliminate units lying below the minimum line and if the test is harmful to units only slightly stronger than the proof load, then it is likely that such testing will be detrimental to design (*a*) and beneficial to design (*b*). In the first case it damages more units than it eliminates and in the other case eliminates more units than it damages.

It is probable that no amount of proof testing, however drastic, can select from carelessly manufactured material a finished batch as dependable as one made in the first instance with good technical control and given routine tests at reasonable levels. This view implies, in specifications, emphasis on consistency of tested characteristics; a carefully drawn sampling plan; a cumulative record of test history so that past experience can be of real value in interpreting the results of samples under immediate review.

It should be noted also that some product characteristics cannot be given routine tests that will check them. Line and station insulators are designed and design-

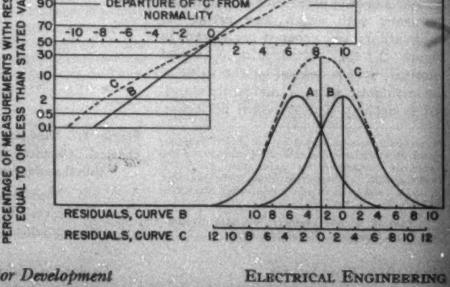

Figure 4. The summation of two normal curves with different $\overline{X}$ values is nonnormal

Inset shows curves *B* and *C* with abscissa values plotted against a probability scale of ordinates. A normal curve so plotted gives a straight line tested to withstand electrical surges of great severity, but so far it has not been practical to surge-test at these extreme levels in routine fashion. Even if it were possible, it might be proved an undesirable practice because of the damaging nature of the tests. In such instances reliance must be placed on methods of quality control which give high-probability assurance that the required characteristic is present.

Estimating and Predicting From Statistical Data

Specifications frequently require certain minimum or maximum characteristics in the product they cover. The best that a manufacturer can do, by conservative rating of his product and by technical control of process, is reduce the probability of a "defective" to some tolerable level. To choose a small sample from a large batch and in that small sample to focus attention on a single value, to the exclusion of other equally significant values and to the exclusion also of the supplier's over-all performance, is certainly uneconomical and may also be unfair. It is quite possible for a chance defective to appear in a product of good quality; and it is more than possible that poor quality will not be detected by looking for a single defective in a small sample. As product characteristics are by nature statistical, assurance of quality in purchasing standards logically might be obtained by stating limiting criteria for the frequency distribution of the quality characteristic in question. Consideration certainly should be given to the average, which is readily established from a small number of samples; to the shift in observed average from batch to batch; and, if additional assurance is needed and when the accumulation of data is adequate, to some measure of the dispersion of values about the average.

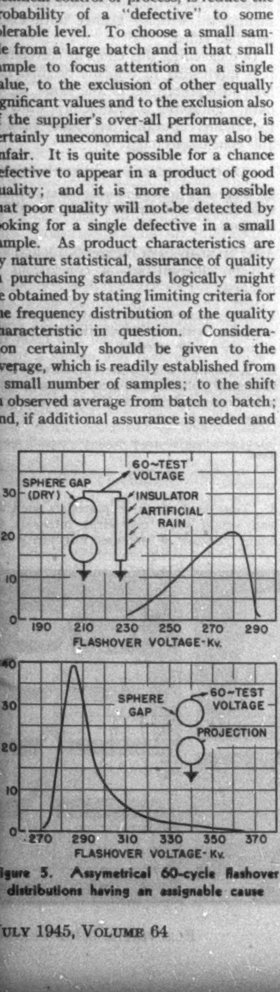

Figure 5. Assymetrical 60-cycle flashover distributions having an assignable cause

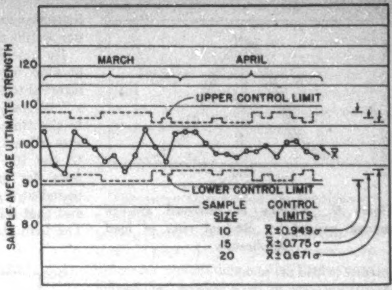

Figure 7. Suspension-insulator control chart

Control is exercised by limiting fluctuation of sample averages with respect to assumed grand average $\bar{X}$

Although statistical methods cannot be expected to indicate such probabilities as one unit in a thousand being below minimum, they are nevertheless the most effective means for estimating limits beyond which not more than four or five units out of a thousand are likely to lie. Their use is indicated particularly in work on new designs for which test information is meager. Illustrative of the general problem of sampling are trials made from a batch of 1,000 specimens having a normal type of distribution and with the specimens divided into nine distribution "cells." The characteristics of the parent distribution were:

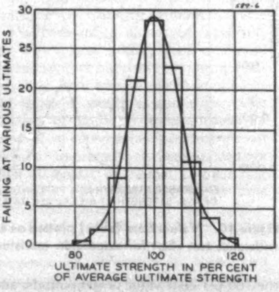

Figure 6. Nine-cell distribution of ultimate strength for a suspension insulator

Average—19,500 pounds
Maximum—23,100 pounds
Minimum—15,900 pounds
Standard deviation—1,245 pounds

As this was an artificially prepared batch, the actual minimum was known to be 15,900 pounds; yet samples of nine specimens each showed the appearance of a minimum unit in only ten per cent of the trials. Even with samples of 50 specimens each, an error of at least 1,000 pounds in observed minimum versus batch minimum occurred in 60 per cent of the trials. In 20 per cent of the trials the discrepancy between observed and batch minimum was more than 2,000 pounds. When the samples reported were analyzed statistically and the expected minimum calculated rather than observed, the error, even on the most misleading sample, was only 600 pounds. The most misleading sample was selected from 40 trials in each of which the sample size was 50 specimens.

Correlation of Product Characteristics

In some instances the determination of a product characteristic is inordinately time-consuming or expensive. If such a characteristic can be related intimately with one for which data are already available (or can be readily obtained) three advantages ensue:

1. The desired characteristic may be estimated.
2. Meager data about the desired characteristic may be expanded and confirmed.
3. Both characteristics may become more intelligible.

Since the characteristics sought are statistical distributions, correlation hardly can be expected between individual specimens. At least in tests that are of the destructive type the correlation must be between frequency-distribution diagrams or between terms defining these diagrams. An example of this approach is

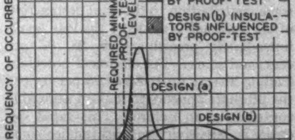

Figure 8. Proof testing in relation to strength distribution

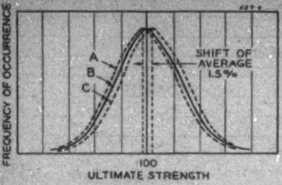

Figure 9. Change in observed average strength caused by different rates of load application

Increase in load per minute:
A—15 per cent of rated strength (minimum)
B—22½ per cent of rated strength
C—30 per cent of rated strength (maximum)

the relation between the ultimate strength of suspension insulators and their performance when endurance-tested, for extremely long intervals of time, by loads of varying severity.

In endurance or time–load testing, insulators are subjected to axial tension for a stated interval of time. In many specifications this is a "withstanding" test in which the failure of any unit is cause for rejection of the lot. To the design engineer, therefore, endurance tests carried to failure are a necessary part of his information about the product. A typical group of endurance-test results is shown in Table I.

It is obvious that interpretive effort has to be made if significant information is to be obtained from these test values. A clue is offered by the shift in strength observed when insulator groups are tension-tested at different rates of load application.

When insulators are tested for ultimate strength, the increase in load per minute may be from 15 to 30 per cent of the rated ultimate strength of the specimen.[3] At these limiting rates the distributions shown in Figure 9 were found. The shift in average strength was about 1.5 per cent.

There is an element of endurance testing in any ultimate-strength test, since the specimen responds to a combination of time and load. Some indication of this is given by Figure 9. The influence of time can be emphasized by rates of load increase that are exceedingly slow.

If the ultimate strength of a particular specimen is designated as 100 per cent, some contribution to the final destruction of the specimen is made by the load levels immediately preceding—99, 98, 97 per cent, and so on. For electrical porcelain loading history up to 85 or 90 per cent of the ultimate appears to make a negligible contribution to failure. This rapid decrease in sensitivity to load implies some type of exponential function. Moreover, since damage by the 99-per-cent, 98-per-cent, and preceding load levels has been assumed, it can be argued that, if it were possible to apply a 100-per-cent load instantaneously yet without shock, failure would not take place immediately.

By a series of tests[3] run at slow rates of load increase it was found that the interval to failure following application of a "100-per-cent" load was about equal to the time spent in going, at a uniform rate of load increase, from the 98-per-cent to the 100-per-cent level. Let us suppose, for example, that an insulator is tested at a 4,000 pounds per minute rate and that failure occurs at 20,000 pounds. The load change from the 98-per-cent to the 100-per-cent value is 400 pounds, and this change is effected in 0.1 minute. The expectation is, then, that, had a load of 20,000 pounds been applied instantaneously and without shock to this particular specimen, failure would have taken place in 0.1 minute.

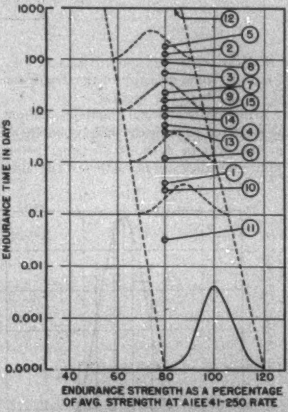

Figure 10. Values from Table I plotted on an endurance-test chart for suspension insulators

In Figure 9, a 100-per-cent change in the rate of load application produced a shift in the distribution pattern of only 1.5 per cent of the observed average ultimate strength. By changing the rates of load increase per minute according to some suitable exponential regression such as 1,000, 100, 10, 1, 0.1, and by testing at each chosen rate a liberal sample of specimens from the same batch of product, a series of distributions is obtained with a three-dimensional relation: observed strength, frequency of occurrence, and loading rate or equivalent endurance time. This expands Figure 9 into the developments shown in Figure 10. On Figure 10 the tabular values for 1938–42 appear rational and significant; they are part of a very much-extended frequency distribution, the plane of which is parallel to the time axis. The model illustrated in Figure 11 shows what might be expected of a complete batch of product if it were subjected to a fixed load and this load maintained without change until every unit had failed.

In concluding this effort at correlation it is interesting to compare original and final interpretations of the same set of data. Following a perfunctory study of the original endurance-test values, reasonable conclusions might be:

1. That the product was extremely erratic.

2. That with better endurance-test strength more consistent intervals to failure would be obtained.

After an analysis of Figures 9, 10, and 11, a very different set of conclusions is reached:

1. The endurance-test observations are consistent with the distribution pattern for ultimate tensile strength.

2. A product with perfect endurance-test resistance, subjected to a continuing load of a size between the limits of its quick-strength pattern would have

(*a*). Immediate failures of minimum strength specimens.

(*b*). Indefinite endurance of maximum-strength specimens.

3. Time–load sensitive materials such as lead would show consistent intervals to failure because of increased angularity be-

Figure 11. Model of Figure 10

Showing:
A—The three-dimensional nature of endurance strength
B—The elongated distribution parallel to the time axis associated with a specific value of test load
C—The influence of width of the distribution pattern in determining endurance time

tween the central plane of the time–frequency–strength solid and the time axis.

4. Statistical methods aid in building a performance structure from which modest extrapolations can be made.

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Winding-Fault Detection and Location by Surge-Comparison Testing

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Synopsis: Surge-comparison methods of testing insulation were investigated with the objective of locating as well as detecting faults. Experience of other investigators was confirmed and limitations of methods and equipment studied. Supplementary methods and equipment were devised to extend the field of usefulness of this basic type of tester, especially to the testing of very large machines with multiple-parallel windings. Apparatus studied included a-c motors from fractional-horsepower single-phase to very large three-phase types; a large variety of d-c armatures; and numerous armature, stator, and magnet coils. This surge-comparison tester has proved to be suitable for use by electrical manufacturers and by service and repair shops, as it can be used for testing most common types of electric windings.

SURGE-COMPARISON testing of electric windings is a new and very useful tool for detecting and locating insulation faults. Foust and Rohats[1] are to be commended for their great contribution to the art. The surge-comparison principle in combination with the cathode-ray oscilloscope opens the way to numerous possibilities for improving insulation testing equipment and technique. The application of a known and controlled voltage surge with visual comparison of the wave shape makes it possible to study insulation faults as well as to detect them.

The work reported by Foust and Rohats[1] was confined to testing of three-phase windings. The authors have extended the field of usefulness of the surge-comparison tester, applying it in its original form and with important modifications to numerous other types of apparatus. Other apparatus studied included d-c armatures, fractional-horsepower single-phase stators, and large three-phase stators. Means for fault location were developed to supplement the original scheme which included only fault detection. Voltage distribution was studied on several types of apparatus.

Description of Test Equipment

The surge-comparison tester is an electronic device designed for two functions:

1. To apply a voltage stress on turn-to-turn, phase-to-phase, and winding-to-ground insulation in coils and wound apparatus.

2. To detect grounded or short-circuited turns in the windings under test.

The turn and phase insulation is stressed by the application of a repetitive surge voltage to the winding terminals. The surge is produced by a charged capacitor, and a high rate of voltage rise is obtained. Because of this high rate of rise, a relatively high test voltage can be applied to most types of windings and coils. The detection of faults is accomplished by means of a cathode-ray oscilloscope on which is impressed the surge voltage across each part or half of the winding alternately. Two standing waves thus appear simultaneously on the oscillograph screen (screen persistence retains the traces between alternate cycles). A divergence or difference in these two waves reveals a dissymmetry in the winding which generally indicates the presence of a fault. The alternate appearance of the two waves is brought about by a synchronous reversing switch which interchanges the surge and ground connections repeatedly. The two detection voltages also may be obtained from exploring coils or other devices close to the winding under test. The applied surge voltage may be varied from zero to maximum as readily as the voltage of the ordinary 60-cycle test box. No other circuit constants can be conveniently changed.

Test Methods

The surge tester used by previous investigators was designed primarily for testing small three-phase induction motors. Three output terminals were provided for connection to the three terminals of the test motor. The surge and the oscilloscope could be connected to any combination of the three motor terminals by means of a manual transfer switch built into the tester as shown in the diagram of Figure 1A. Nearly all small three-phase motors can be tested for weak insulation and faults in the manner illustrated by this diagram.

Individual coils, single-phase motors, or other pieces having no inherent three-phase symmetry may be tested in pairs as shown in Figure 1B. Here one coil or winding of a type is used as a standard for comparison testing of other similar pieces. This method was applied to all coils and miscellaneous windings tested. A comparison method also was found useful in d-c armature testing. The surge was applied to the commutator at points one brush span apart with a third contact midway between to form the mid-point for the two-winding comparison scheme. Figure 1C illustrates this simple adaptation.

Variations from the connection arrangements of Figure 1A and 1B were made for certain tests and will be described in a discussion of the results. The surge test voltage used was generally made equal to the peak of the specified rms high-frequency test[2] voltage.

Cores or frames of all apparatus tested were always grounded during test for several reasons: to increase the operator's safety, to keep the voltage from conductors to iron at a known value, and to eliminate the effects of minor variations in capacitive couplings. The surge-tester frame also was always connected to a ground.

Results of Tests

The application of the surge tester and the results obtained will be described briefly for each type of apparatus tested.

Armature and Stator Coils

Coils of various sizes from three-turn coils 16 inches long to ten-turn coils 36 inches long were tested as in Figure 1B. Faulty insulation and short-circuited turns were readily detectable in most coils. Examples are shown by the delineation, Figure 2A, of the oscilloscope-

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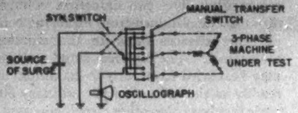
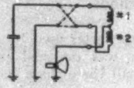
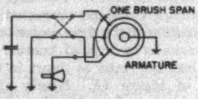


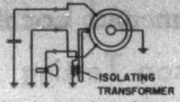
A. Three-phase test



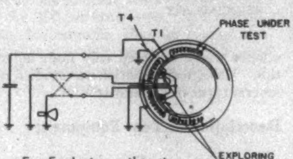
B. Two-coil comparison test



C. Armature comparison test



D. Armature bar-to-bar test



E. Exploring-coil testing

Figure 1. Circuits used in testing

voltage traces of two ten-turn synchronous-motor coils. Corona or arcing present in some coils could be detected readily and the voltage at which it started determined. Burning or heating of faults in coils usually was not great enough to facilitate exact location of the faults. This was due to the fact that the average power output of the surge generator is necessarily low because of the short duration of the impulses.

Field Coils

Many types of field coils were tested using the connection of Figure 1B. Excellent detection of one short-circuited turn was obtained with coils having either air or iron cores. Slightly better results were obtained with the types having the iron pole in place, but as shown by Figure 2B, detection of a short-circuited turn in a 477-turn air-core coil was very satisfactory.

Armature

Numerous types of railway and d-c generator armatures were tested. Dead grounds and short circuits were detected very satisfactorily using the comparison connection, Figure 1C. A typical example is Figure 3A which shows clearly the visual evidence of a dead short-circuited coil midway between the surge and oscillograph contacts on the commutator of Figure 1C. Armatures lying on the floor were tested by this method by use of a portable contact arm. Insulation could be tested completely by moving the contacts once around the commutator. Movement through one brush span served to detect faults as a preliminary test.

The comparison method was found inadequate for locating a short circuit or ground in cross-connected or wave-wound armatures. To overcome this difficulty the bar-to-bar voltage-measuring circuit of Figure 1D was devised from equipment used with the high-frequency test.[2] With this arrangement, dead short-circuited or grounded coils were located exactly and quickly in any of the armature types tested. Arcing or intermittent short circuits were detected easily by either method, but too few examples of this type of fault were found to permit development of a satisfactory means of locating them.

Single-Phase Motors

The testing of fractional-horsepower single-phase motors was accomplished by

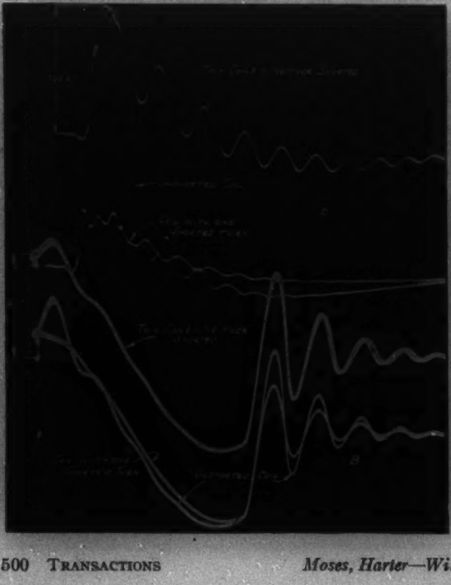


Figure 2. Short-circuited turn detection in stator and field coils

A. Ten-turn stator coils
B. 477-turn field coils. (No iron present)

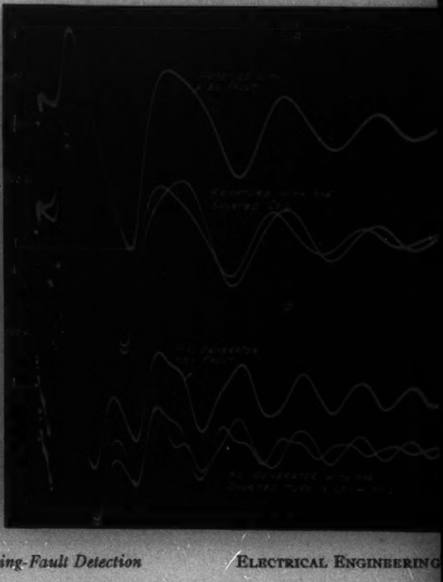


Figure 3. Short-circuited turn detection in a large d-c armature and in an a-c generator

A. Large d-c motor armature
B. Large a-c-generator

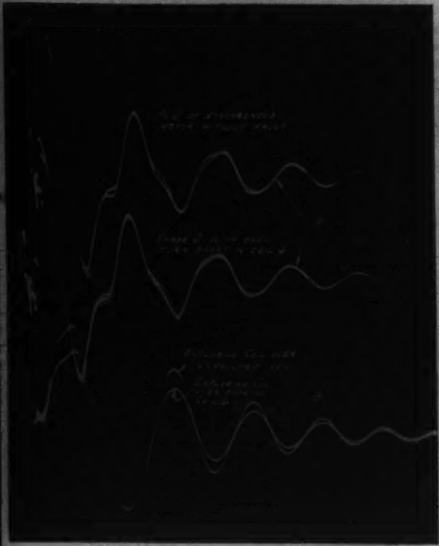


Figure 4. Tests on large synchronous motors

Comparison of detection of a single-turn short circuit in a winding having 12 parallel conductors per phase when tested by the two methods: simple phase comparison and exploring-coil comparison

A. Three-phase comparison test

B. Single-phase test using exploring coils

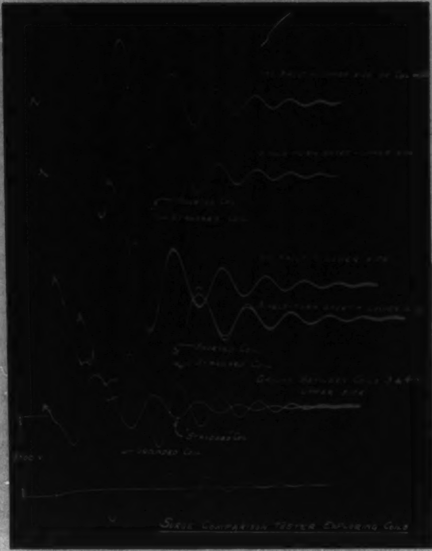


Figure 5. Exploring-coil voltage traces during test on large synchronous motor

One exploring coil over first the upper and then the lower side of a faulted coil in a winding with 12 parallel conductors

comparison either of two similar motors or of the two halves of a single winding. Both of these variations in the comparison technique yielded satisfactory results in the detection of short-circuited or grounded coils. One short-circuited turn in as many as 1,000 total turns was easily noticed.

THREE-PHASE MACHINES

Three-phase motors and generators of various sizes were tested with a surge-comparison tester. The simple phase-to-phase testing method, Figure 1A, permitted unmistakable detection of short-circuited or grounded coils in all windings of relatively few parallel circuits. Figure 3B illustrates the detection of a single-turn short-circuit in a large three-phase winding of 21 turns per phase. Detection of one-turn short circuits also was satisfactory in smaller motors having as many as 600 series turns per phase.

In windings with many parallel circuits, detection as well as location of a short-circuited turn or coil was found impossible with the simple conventional circuit of Figure 1A. This condition is illustrated by Figure 4A, which gives the result of a test on a very large synchronous motor which had 12 parallel circuits per phase, each consisting of eight ten-turn coils. Short-circuiting out one turn in phase $T1$-$T4$ of this winding made a nearly imperceptible difference in the voltage traces which actually made the winding look better than it did with no short circuit. Furthermore, inherent winding dissymmetries in these large motors caused oscillograph trace differences which added to the uncertainty. A close inspection of Figure 4A reveals the fact that the trace differences present in the unfaulted winding are greater than those caused by a short-circuited turn.

Because of these difficulties, the problem of detecting and locating faults in the windings of large three-phase machines with this tester was attacked first by using the simple comparison scheme of Figure 1B to compare the separate parallel circuits before connection to the paralleling rings. This method generally was satisfactory and made detection of a coil having a single short-circuited turn easily possible. Testing of the winding after completion also was desired, however, and the circuit and auxiliary equipment of Figure 1E ultimately were devised. With this method a unidirectional repeating surge voltage is applied to a terminal of one phase of the winding to stress the turn insulation and break down any weak places; the other terminal is grounded. While one phase at a time is thus placed under test, two identical exploring coils are moved by hand around one revolution in the bore of the machine. These coils are attached to the ends of an adjustable arm and so spaced as to be located over two winding coils that lie in identical electrical positions but in adjacent parallel circuits of the phase being tested. Since the two coils in the winding must react alike to the surge voltage if no fault is present, their emitted flux induces identical voltages in the two exploring coils. The induced voltages are compared by means of the oscillograph and synchronous reversing switch in a manner similar to that of the comparison connection of Figure 1B. A fault in either winding coil will cause a reduction in its flux, and hence a difference will appear in the oscillograph traces. By virtue of the complete revolution of the exploring coils, every coil in the phase will be compared with two other coils. The effect of a short-circuited turn in a winding coil under one of the exploring coils is illustrated by Figure 4B. The exploring coils used were wound on C-shaped iron cores. In Figure 5, a complete set of traces is shown for the exploring coils located over upper and lower sides of the faulted coil both with and without the fault of one short-circuited turn. The surge applied to the winding is included at the bottom of the page. This trace shows the extremely high rate of

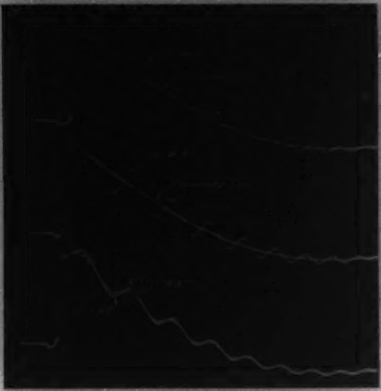


Figure 6. Oscillograms showing the possible effect of variations in varnish treatment on surge voltages

Railway-motor field coils. Coils 8 and 9 were varnish-impregnated; the standard coil was left untreated

voltage rise across the winding (0.3 microsecond to crest).

Ground faults in any device could be detected unmistakably with the original tester circuit and equipment, but the location of grounds in large motors and generators required the use of the exploring coils and the new circuit in the manner just described. With the exploring coils, the location of a ground in any group of series coils could be narrowed down quickly to two adjacent coils. This location of the approximate position of the ground was based upon the fact that coils from the surge application terminal to the ground will induce voltages above normal, whereas those from the grounded coil to the grounded terminal will induce voltages far below normal. The exact coil then was found by opening the winding between the two coils in question and reapplying the surge and exploring coils. The connection opened always was one of the two which later would necessarily be broken to remove the grounded coil.

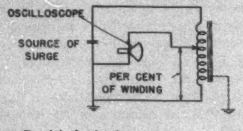


Figure 7. Method of measuring surge peaks

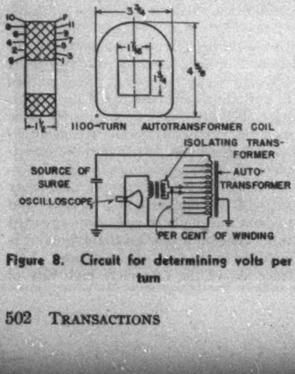


Figure 8. Circuit for determining volts per turn

Magnet Coils

Tests were made on air-core magnet coils using the two-coil comparison connection, Figure 1B. One short-circuited turn in as many as 4,000 was readily detected. The maximum number of turns in which one short-circuited turn could be detected was not determined exactly, as it depends somewhat on the size and shape of the coil, but the limit appeared to be about 10,000 turns.* Above 10,000 turns only a short circuit of several turns or more could be detected satisfactorily. The application of an appreciable turn-to-turn voltage stress was possible only in coils which had relatively few turns because of the practical limit to the available test voltage. Another and possibly more important obstacle to high turn-to-turn voltages in magnet coils is the fact that most coils are not provided with terminals and leads capable of withstanding the high total voltage which would be required.

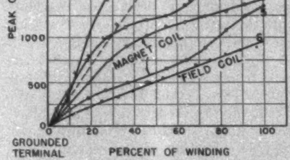


Figure 9. Surge-voltage distribution in four types of coils

Curve 1. Large d-c armature
Curve 2. 1,100-turn autotransformer—surge to inner lead
Curve 3. 1,100-turn autotransformer—surge to outer lead
Curve 4. 35,000-turn magnet coil—surge to inner lead
Curve 5. 35,000-turn magnet coil—surge to outer lead

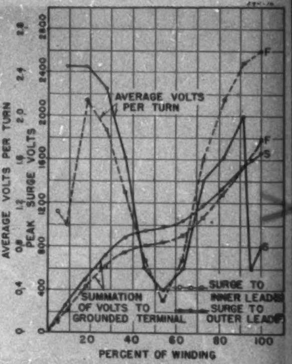


Figure 10. Average volts per turn in an autotransformer calculated from measurements obtained as in Figure 8

General Observations

Winding dissymmetries may cause differences in the voltage traces of two supposedly identical coils or windings even though no faults exist. This was observed often during tests on the apparatus described in this paper. Examples are the traces of Figures 2B and 4A. Many windings and coils seemingly have inherent dissymmetries caused by differences in their varnish treatment, amount of fill, moisture present in the winding, or unknown causes. An extreme example of this is illustrated by tests on three main field coils for a railway motor, Figure 6. Coils 8 and 9 both were impregnated in black solventless varnish and dipped in Thermoset varnish. The only difference in these two coils was in the resin treatment on the glass turn insulation. The standard coil was untreated and had mica-tape turn insulation. It may be seen that the voltage traces of the two treated coils have a superimposed oscillation caused by the presence of the resins (which increase the distributed capacity). The two treated coils, furthermore, are not identical owing to a difference either in the two resins or in the degrees of penetration into the coils. These effects of winding dissymmetries sometimes have caused uncertainty as to whether a fault was or was not present in the device under test. Nearly all examples of this uncertainty, however, were readily eliminated in a practical manner by placing the minimum possible fault, usually one short-circuited turn, in the winding and observing the effect. One short-circuited turn usually produced the greater and more unmistakable effect in most types of armature, field, and magnet coils, and in small machines with few parallel circuits. The inherent dissymmetries of large multiparallel windings, as previously discussed, rendered detection of short-circuited turns by the simple comparison scheme impossible.

Distribution of voltage magnitude across the winding turns of several representative pieces of apparatus was determined. This was first done by using the oscillograph in the tester simply to measure voltage from the grounded terminal of a winding to taps through the winding. Peak voltages only were recorded, and, as these occurred at nearly the same time after application of the surge, time differences were neglected. The method is illustrated by Figure 7. Data obtained in this manner yielded the curves of Figure 9. Additional measurements using a revised circuit, Figure 8, then were made on the autotransformer of curves 2 and 3 of Figure 9. The actual voltages between taps of the transformer were measured and the average volts per turn calculated. These data are plotted in Figure 10. Since this shell-type transformer had been chosen for its extremely nonuniformly distributed capacitance and inductance, its surge voltage distribution curves reveal approximately the worst condition that is likely to be present in any type of winding during this surge test. This uneven distribution, of course, could be improved by minor test-circuit revisions to reduce the steepness of the surge-voltage wave front.[5] The wave applied to this transformer had a time to crest of about 0.2 microsecond.

Figure 11. Comparison surge tester in use on large stator winding with many parallel circuits

The surge-comparison tester thus has been tried on numerous samples of all common types of coils and windings. In general, it was found to be a satisfactory test for many insulation-testing applications. The use of the cathode-ray oscilloscope for detection of faults permits accurate measurement of voltage when desired, gives the operator a view of the manner in which the winding is being tested, and, furthermore, reveals any arcing, corona, or other unusual phenomena occurring in the winding. The oscilloscope, however, does not provide a definite quantitative distinction between faulted or unfaulted windings. The interpretation of the oscilloscope evidence, however, could become easy and positive with experience on any particular application.

The problem of fault detection and location has been largely restricted in this paper to faults involving short-circuited turns or coils. Ground-fault detection was found easy and distinct in all windings so that no refined technique was necessary. In fact, any ground fault found in a winding during test had to be cleared up before other faults could be detected as its effect was to upset completely the symmetry of the winding. The location of grounds was attempted only on armatures and large three-phase machines, both of which have been discussed.

No circuit constants of this type of tester need be varied by the operator except the test voltage, which is set by turning a tap switch or a calibrated dial. The wave shape is fixed by the tester circuit components in conjunction with those of the winding on test. The connections for testing are simple and nearly the same for most types of apparatus.

Conclusions

The surge-comparison insulation tester is a highly versatile tool which, with further development, could be applied to many insulation testing problems. It possesses the following desirable or advantageous features:

1. The test voltage may be readily preset to any desired value which will not vary during the testing except with the line-voltage changes. The test voltage may not always be the same for different sizes of windings, however, because of the voltage drop in the protective resistor which becomes appreciable if the device under test has a relatively low surge impedance.

2. Control of the machine is simple and easy. Only the voltage requires setting by the operator, in addition to the usual control knobs for the oscilloscope.

3. Setting up for test usually is reduced to mere connection of three leads. No auxiliary equipment is needed for most testing, and testing instructions are simplified.

4. The surge tester is flexible; large generators or small magnet coils may be tested with no change in circuit constants or connections, except for the testing of windings with many parallel circuits.

5. The cathode-ray oscilloscope gives the operator a constant view of his test voltage and its effect on the winding. Arcing and corona can be detected along with steady-state faults. The oscilloscope also may be used to measure voltage to ground at any point.

6. The voltage stress applied to ground insulation is kept to a limited and known value, because cores and frames can be grounded. Personal safety also is increased by having all parts of a machine except conductors at ground potential.

7. The surge voltage applied has a wave front at least as steep as the wave fronts of most switching and lightning surges which are the sources of dangerous overpotentials in service.

8. The tester can be built as a relatively compact and lightweight unit which can be moved about easily for testing in numerous locations.

9. D-c armatures may be given an insulation and fault-detection test while lying on the floor or in winding frames and need not be placed in a special testing lathe as is now necessary with some conventional methods.

10. Photographic records may be easily made of any test to show unusual results obtained or for future comparison with other tests.

11. Grounded coils in large a-c machines can be located without the puncturing of insulation with probes or the unnecessary breaking of connections.

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Precision Testing of Electric Tachometers

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Synopsis: The magnetic-drag electric tachometer which was developed especially for the measurement of aircraft-engine speed is inherently a more precise measuring device than those instruments which normally have been used as reference standards of speed measurement. This paper describes an electric-tachometer testing system which meets the requirements of high accuracy and is also suitable for large-quantity manufacture of tachometers. The system provides facilities for testing at 22 scale points in a range of speeds from 500 to 4,500 indicated rpm without referring to a standard instrument. The power to drive the tachometers being tested is supplied from tachometer generators which are driven by a d-c motor controlled by a precision tuning fork. The method of operation and the control system are explained.

AMONG the outstanding aircraft instruments developed to meet the urgent needs of the armed forces is the magnetic-drag electric tachometer.[1,2] This tachometer consists of an indicator, Figure 1A, and a three-phase synchronous generator, Figure 2. The indicator is mounted on the instrument panel, and the generator is coupled directly to the aircraft engine. The generator voltage, of frequency proportional to engine speed, operates a synchronous motor in the indicator. The disassembly view in Figure 1B shows the magnet assembly which is rotated by the motor. The magnet assembly is arranged so that an aluminum-alloy disk fastened to a shaft and pointer assembly and supported in independent bearings is displaced by electromagnetic torque against a spring-restoring torque. A pointer deflection thus is produced which is proportional to the speed of the rotating magnets or to the frequency of the generator output, and therefore to engine speed. As the indicator is a frequency-sensitive device, variations in magnitude of the generator output voltage do not influence the accuracy.

The inherent accuracy of the tachometer indicator and high-quantity production required that special test equipment for checking calibration be developed. Early methods of testing tachometer indicators were accomplished by manual control of the speed of a d-c motor driving the transmitting element of the tachometer being tested and by comparison with a reference standard. For each calibration point to be tested, the correct motor speed was adjusted manually according to the indication of the reference standard, and then the indication of the instrument being tested was observed. When a large number of scale points were to be checked, this procedure became lengthy and susceptible to the hazards of serious personal errors. Even more important, however, was the fact that the available standard tachometers, even those of the liquid type, were accurate to only ±0.2 per cent of full-scale calibration. These were not satisfactory for testing the aircraft tachometer, because the required accuracy of calibration as shown in Figure 1C is of the same order of magnitude.

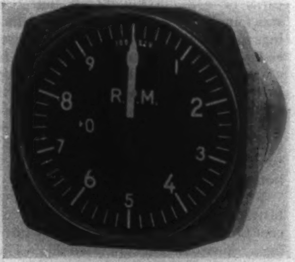

Figure 1A. The magnetic-drag electric tachometer indicator

When performed by the early methods of point-for-point comparison with a reference standard, testing is both slow and inaccurate. The well-known synchronizing-fork type of equipment, though accurate to ±0.1 per cent, is not adaptable to high-production testing. A tuning fork in this equipment provides means for manually synchronizing the speed of a d-c machine to which is coupled a tachometer generator through a step-ratio gear train providing a large number of test points.

The development of high-precision standards of frequency measurement[3,7] and automatic speed control has made the means available for vast improvement over old methods of tachometer testing. Described in this paper is a tachometer testing system which meets the requirements set by high-production rates and high accuracy.

Test Requirements

All of the testing operations require that voltage of a correct frequency corresponding to the desired scale point be applied to the indicator. These operations include: adjustment of bearings and adjustment of the full-scale point by reducing the magnetic strength of the rotating drag magnets. The entire calibration through 22 scale values then is checked both for increasing and decreasing frequency as well as for various angular positions of the instrument.

The most desirable method of performing the testing operations is to have available for immediate selection a series of voltage sources of the correct fre-

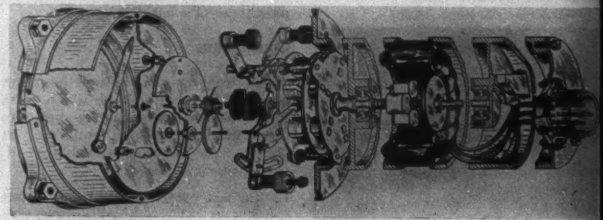

Figure 1B (above). Disassembly view of tachometer indicator

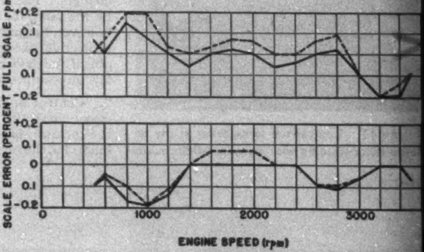

Figure 1C (right). Typical calibration curves

—— Engine speed increasing

– – – Engine speed decreasing

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igure 2. Tachometer generator which furnishes three-phase power to the indicator

uencies corresponding to the desired cale points. The indicator then can be orrectly energized and the adjustments nade without reference to a standard. he success of this method requires that ach frequency corresponding to a scale oint on the indicator be extremely acurate. An allowable error one-tenth hat required of the tachometer-indicator alibration would be acceptable, although higher accuracy, of course, is desirable.

Techniques of frequency measurement sing piezoelectric crystals and precision uning forks maintained at constant temerature have been developed to a high egree. It is now possible to measure requency over a wide range to a preision of only one part in 10,000,000. By ncorporating automatic control with the ynchronizing-fork method of tachometer esting and utilizing these new techniques f frequency measurement, it has been ossible to obtain testing equipment havng an over-all precision of better than 0.01 per cent.

est Equipment

The line diagram, Figure 3A, shows he arrangement of the components in his equipment. The principal components are:

Test stand.
Gearbox and tachometer generators.
D-c motor.
Pilot generator.
Motor field control.
60-cycle frequency standard.
Oscilloscope monitor.
60-cycle laboratory standard of freuency using a piezoelectric crystal.

The gearbox, Figure 3B, drives a group f tachometer generators which supply oltage for testing at 22 different freuencies corresponding to the scale points n the tachometer indicator. Gearbox, -c motor, and pilot generator all are onnected to a common drive shaft hrough a two-to-one, one-half-to-one, one-to-one multiplier designated in the diagram as a gear shift. This unit extends the usefulness of the equipment to more than one instrument scale range. Speed of the drive shaft is maintained constant by control of motor field current by the field-control unit as determined by the deviation in frequency between the pilot-generator voltage and the reference signal from the tuning-fork standard. The pilot generator is a four-pole 60-cycle alternator, and the tuning-fork standard provides the 60-cycle reference signal. Continuous indication of the speed of the main drive shaft is obtained by comparing the frequency of the pilot-generator voltage with a voltage from the laboratory standard of frequency on a cathode-ray oscilloscope.

Terminating in a convenient test stand, Figure 4, are the voltage circuits from the group of tachometer generators. Through a series of interlocked push buttons, the tachometer being tested may be connected to the desired generator and thereby become energized at the precise frequency corresponding to the particular scale point. Reference to a standard tachometer is unnecessary as voltages for the scale range from 500 to 4,500 indicated rpm in the 22 specified steps are selected. The testing operation thus is so materially simplified that it can be accomplished in a few minutes by a relatively unskilled operator. When performed by a skilled operator, according to the early methods of testing, the operation required from 20 minutes to one-half hour. Moreover, the test stand is equipped with a knock-down coil necessary for the adjustment of the full-scale point. This coil is conveniently arranged so that the magnetic strength of the indicator drag magnets may readily be reduced while the instrument is mounted in the test stand.

The equipment was designed to provide for four of the test stands shown in Figure 4. Additional facilities were added by the use of three-phase power amplifiers.

Figure 3A. Line diagram of complete tachometer testing system

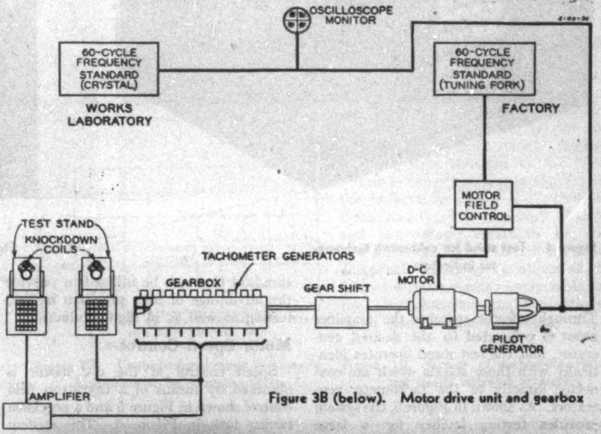
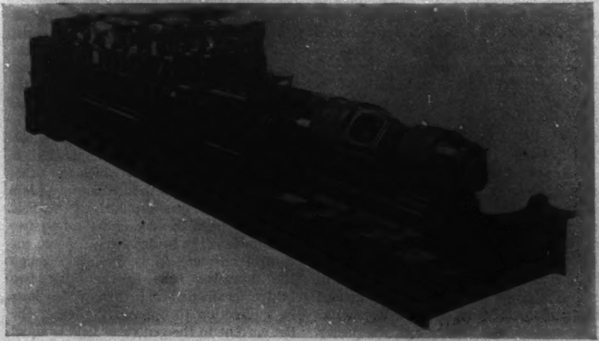


Figure 3B (below). Motor drive unit and gearbox



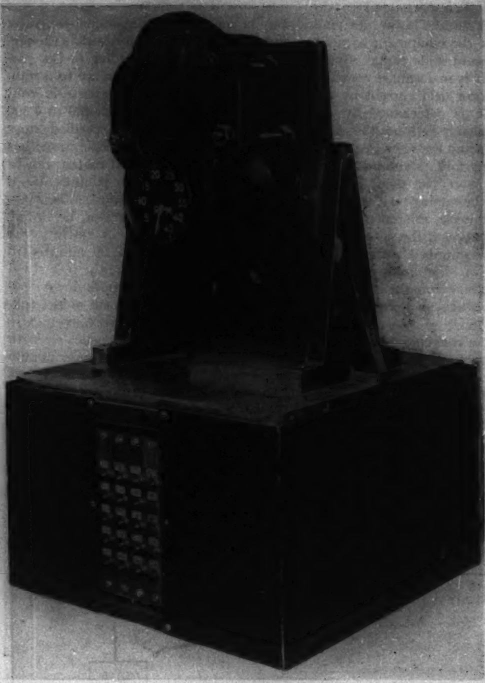


Figure 4. Test stand for calibrating tachometer indicators

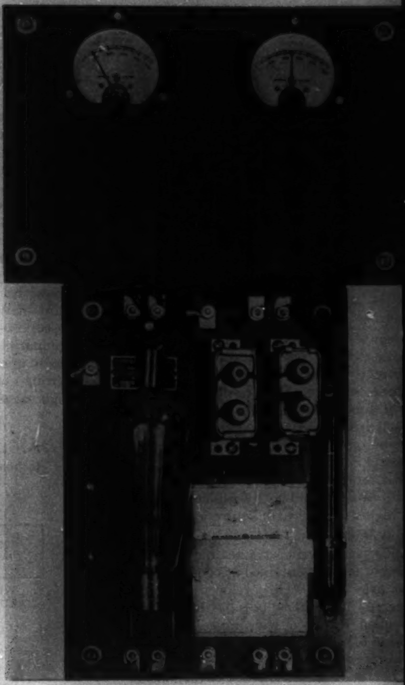


Figure 5. Field-current control panel

Through selector switches the amplifier input is connected to the desired generator, and the test stand operates identically with those stands which are connected directly to the tachometer generators. As shown in Figure 5, the system provides testing facility for a large number of testing stands to be operated simultaneously. Since the amplifiers draw no additional load from the generators, the testing facilities can be extended to meet any desired requirement of increased production. Smaller generators, such as magnetized gears or tone wheels, also may be used to furnish the range of frequencies desired if their output is supplied only to the amplifiers.

A modified testing system using small generators and one amplifier with the associated frequency standard and controlled-speed motor might be applicable in field testing of tachometer indicators. An even simpler arrangement for field testing might be developed by the use of an oscilloscope and frequency standard but with manual control of the d-c motor. The use of the tuning-fork frequency standard thus can be utilized to provide the advantage of high precision in field testing as well as in high production.

Motor Speed Control

Speed control of the d-c motor is obtained by means of a thyratron field control shown in Figure 5 and a precision tuning fork in Figure 6. This system of motor speed control was developed originally for turbine-governor application[6] where large power variations exist. As a precise tachometer testing system, it is subject to the same variables as well as variations in line voltage. But the magnitude of the variations is small and controllable.

The control circuit in Figure 7A shows the motor field windings connected in two arms of a bridge of which the other two arms are equal fixed resistors. Main field current I_f, is supplied to the field windings from the d-c line through two terminals of the bridge circuit, while the control current, I_c, is applied through the thyratron tube to the other two bridge terminals. The current, I_c, flows in a direction to oppose I_f; hence, the net current to the generator field is equal to I_f minus the average value of I_c. Any tendency for the motor to change speed is opposed by a restoring torque produced by a change in I_c, and consequently in the net field current.

The magnitude of I_c is controlled by the phase relation between the voltage E_g applied to the thyratron control grid and the plate voltage E. The voltage

Figure 6. Precision tuning-fork frequency standard

E is obtained through transformer T_1 from the single-phase pilot generator which is connected directly to the d-c motor and gearbox drive shaft. The frequency of its voltage is proportional to the shaft speed. The voltage, E_g, is the vector sum of a standard voltage, E_f, obtained from a tuning-fork standard oscillator shown in Figure 6 and a voltage E_s from the pilot generator. Through the phasing network in Figure 7A, the voltage E_s from T_2 is brought in phase quadrature with the plate voltage E.

Plate- and grid-circuit relations are best described by referring to Figure 7B. As both E and E_s are supplied from the pilot generator, small changes in motor speed will not alter their phase relation. However, small changes in motor speed will be followed by a phase displacement between E and the tuning-fork voltage E_f. Thus, as the motor speed tends to increase, the resultant grid voltage becomes displaced in phase in the direction of the upper arrow in Figure 7B. A shift in phase in this direction causes a decrease in the average value of I_c. As I_c flows in a direction to oppose the main field current, I_f, a net increase in motor field strength results, and the tendency for the motor speed to increase is opposed. The opposite action takes place when the motor speed tends to decrease. The displacement of the grid voltage E_g is now indicated by the direction of the lower arrow in Figure 7B. The resulting increase in the average value of I_c causes the motor field strength to decrease, thus opposing the tendency of the motor speed to decrease.

Accuracy of Calibrating System

The factors which affect the performance of the speed control are:

1. Tuning-fork error.
2. Temperature variations.
3. Load variations.
4. Line-voltage variations.

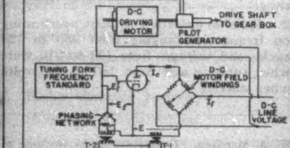


Figure 7A. Field-control circuit

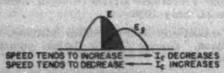

E
E_g
SPEED TENDS TO INCREASE ——→ I_c DECREASES
SPEED TENDS TO DECREASE ←—— I_c INCREASES

Figure 7B. Plate- and grid-voltage phase relation

The precision of the system is established principally by the magnitude of the frequency deviation of the tuning-fork oscillator.[3] The tuning fork in this unit is maintained at constant temperature, and its maximum frequency deviation does not exceed ±0.003 per cent.

Temperature, load, and line-voltage variations which operate to exceed the control range of the current I_c, Figure 7A, will cause the system to drop out of synchronism. Figure 8A shows the range in control current for variations in line voltage while the load is constant. Figure 8B shows the control current range when the line voltage is held constant and the load varied. Only temperature variations caused by self-heating of the equipment cause the control range of I_c to be exceeded, and for this condition a compensating adjustment of I_f is made after stable thermal conditions have been established. Variations in load and line voltage which do not operate to exceed the control range of I_c contribute to the over-all error of the system by introducing hunting. This is kept to a negligible value, largely because the line voltage is obtained from an independent supply having good regulation; and the intermittent loading of the tachometer generators as tachometer indicators are alternately connected and disconnected is small.

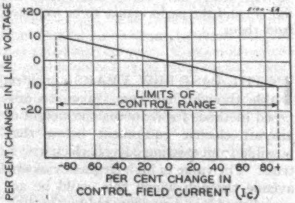


Figure 8A. Control-current range in terms of line-voltage variations for constant load

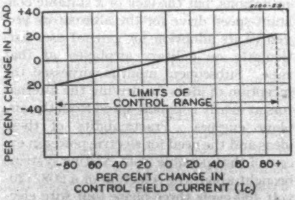


Figure 8B. Control-current range in terms of load variations for constant voltage

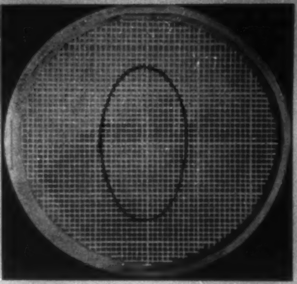


Figure 9. Lissajous figure on oscilloscope screen

A detailed study of the conditions influencing hunting is beyond the scope of this paper. It is evident, however, that the time constant of the control system is dependent almost entirely upon the inductance in the d-c motor field. Consequently, it is necessary that load and line-voltage variations be small. The curves in Figure 8A and 8B indicate acceptable limits of variations of these factors without causing appreciable hunting. By observing the precautions of small load changes and steady d-c line

Figure 10. Group of tachometer-indicator test stands installed in factory

voltage the over-all accuracy of the system is within ±0.01 per cent.

Continuous Reference to Primary Standard

Continuous check of the precision of the base speed and therefore to any one of the test points is obtained by reference to a standard signal from a piezoelectric crystal oscillator. A 60-kilocycle crystal and associated multivibrator stages are standardized daily with standard time signals from the Bureau of Standards radio station WWV. The precision of the 60-cycle output of the oscillator is better than ten parts in 1,000,000. This signal is wired to the factory testing system and connected to the vertical plates of a cathode-ray oscilloscope located prominently in the testing area. Connected to the horizontal plates of the same oscilloscope is the voltage output of the pilot generator in Figure 3A. Figure 9 shows the Lissajous figure formed by the two signals applied to the oscilloscope. The rate of displacement of an element of this figure is a measure of the deviation in frequency of the two applied signals. Displacement of one degree per second of a point on the image formed on the oscilloscope screen corresponds to the over-all error of 0.01 per cent and can be detected readily.

Conclusion

The convenience of operation and precision of the tachometer calibrating system as a factory testing device is apparent. Skill in accomplishing the tachometer calibrating operation is reduced to a minimum and an operator can be trained in a matter of hours. The testing time over early test methods has been reduced from one-half hour to a few minutes per instrument, thus making the large production requirements possible with a minimum of increase in personnel.

The use of such equipment because of its complexity and size is necessarily limited to use in high-production testing. Obviously, such a system is not adequate for field testing of electric tachometers. However, modifications in the applications of the oscilloscope, d-c motor with manual speed control, and the standard-frequency oscillator, can be adapted for small testing requirements. Such modification would retain the advantages of precision over the conventional types of standards for the testing of tachometer indicators.

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A 400-Cycle Aircraft Motor

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Synopsis: The ever-present need for lighter-weight and more compact aircraft electric motors is evident as any reduction in weight or space provides increased fuel, bomb, or pay-load capacity. Reliable 400-cycle motors more compact and approximately 40-per-cent lighter than existing 24-volt d-c motors have been developed recently. Present trends indicate that these motors will be used extensively aboard the airplane of tomorrow. This paper describes some of the 400-cycle motors that have been developed and discusses their requirements with the view of disseminating information so that others may better understand the motors and the performance to be expected from them.

In the past few years considerable thought has been given to proposed methods for reducing the weight of aircraft electric equipment below that possible from existing 24-volt electric systems. The value of high frequency as one avenue through which this could be accomplished was demonstrated by the 400-cycle electric system aboard the *B*-19 airplane built some time ago. This system functioned satisfactorily according to expectations, but the lack of a suitable constant-speed drive for the alternators prevented its adoption for general use, particularly on military airplanes, at that time. Subsequent months witnessed the inception of ideas for driving the alternators at nearly constant speed from the airplane engines. Practicability of these ideas and the need for electric power in excess of that possible from existing systems brought about the selection of a 208/120-volt 400-cycle three-phase four-wire electric system for several military airplanes under consideration.

Heretofore knowledge of the electric motors developed for use on these and other airplanes has been confined, generally, to the few intimately associated with their design. Much of the accumulated information pertaining to their design and application may be useful, particularly to aircraft electrical engineers or others who will apply the motors. Therefore, this paper was written, primarily from a design point of view, for the purpose of disseminating some of this information so that others may better understand the motors and the performance to be expected from them. It contains the following material:

1. A summary of the motor requirements.
2. The principles of operation compared briefly with those of 60-cycle commercial motors.
3. A comparison of characteristics with those of existing d-c aircraft motors.
4. The design factors involved.
5. A discussion of the motor characteristics related to loads encountered aboard aircraft
6. Illustrations and characteristic curves representative of a line of motors that has been developed.
7. Conclusions.

Requirements

The more important motor requirements mutually agreed upon by the United States Army, Navy, Air Force Command, interested motor manufacturers, and representatives of the aircraft industry are summarized as follows:

1. Dependable operation from -70 to $+60$ degrees centigrade according to National Aircraft Standards Committee charts at all altitudes to 40,000 feet and in all humidities existing within this altitude range.
2. Reliable operation without overheating on frequencies ranging from 380 to 420 cycles and voltages from 190 to 210 volts when running and from 180 to 210 volts when starting.

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3. Ability to withstand shock and vibration encountered aboard airplanes.

4. High efficiency and power factor to permit minimum weight of associated electric equipment.

5. Small size and light weight consistent with other requirements.

6. A life of 500 hours without undue servicing on the specified duty cycle, preferably more.

7. Simplified construction arranged for easy servicing.

8. Intermittent-rated motors must operate on a duty cycle of one minute on and 20 minutes off. Their locked-rotor torque must be 300 per cent of the rated torque on normal voltage and frequency and at 25 degrees centigrade ambient temperature. The slip at rated torque must not exceed 15 per cent of the synchronous speed.

9. Continuous-rated motors must have 200-per-cent breakdown torque and 160-per-cent locked-rotor torque, both in terms of rated torque on normal voltage and frequency and at 25 degrees centigrade ambient temperature.

Comparison With Other Motors

These motors, most of which are three phase four wire, possess principles of operation similar to those applicable to 60-cycle motors of the same type. Generally the same fundamental laws and formulas applicable to 60-cycle alternating motors are usable although instances occur where it is necessary to modify or extend associated empirical data to embrace new conditions. They differ from the 60-cycle motors chiefly as follows:

1. Higher operating speed.

2. Smaller size and less weight for corresponding horsepower ratings.

3. Better material utilization—electrically, mechanically and thermally—to obtain lighter weight without sacrificing reliability.

4. Ability to operate over increased temperature, humidity, and altitude ranges.

Their characteristics compared with those of existing 24-volt d-c aircraft motors, segregated according to merit, are listed in the following paragraphs.

DESIRABLE CHARACTERISTICS

1. Lighter weight and smaller size for same output rating.

2. Higher efficiency, generally.

3. Simplicity of construction.

4. Absence of commutators and brushes which are difficult to maintain, particularly at high altitude, and which may permit erratic motor operation because of their susceptibility to external vibration.

5. Higher operating voltage and lower currents which permit a reduction in the weight of wiring and generating equipment.

6. Inherently longer life with less servicing.

7. Less speed variation over the normal load range, including that caused by normal voltage and frequency variations. This does not apply if the speed of the direct motor is controlled by a speed regulator.

8. Freedom from explosion-producing properties such as sparking at brushes.

9. Reduced voltage regeneration and hence less danger of damage to motor and system if direction of rotation is instantly reversed.

10. Inherent regenerative braking for overhauling loads.

11. Generally, a lower ratio of starting to running currents, a condition which makes it possible to simplify the design of associated equipment.

12. Easier to apply thermal overload protection.

13. Reduced rotor inertia—hence less braking required to stop motors in the same length of time.

14. Reduced danger of damage or faulty operation from corrosion of vital parts.

15. Moderate ratio of locked-rotor to running torque. D-c motors have locked-rotor torques up to about 1,000 per cent of their rated load torques. Continuous-rated a-c motors according to specifications have 160-per-cent locked-rotor torques. Intermittent-rated 400-cycle motors according to specifications have 300-per-cent locked-rotor torques.

16. Less filtering required to eliminate radio interference.

UNDESIRABLE CHARACTERISTICS

1. Locked-rotor and breakdown torque variations, caused by both voltage and frequency changes rather than voltage changes alone.

2. Lack of speed control.

Many engineers would list the moderate ratio of locked-rotor to running torque as an undesirable characteristic, as any increase in this torque is added assurance that the motors will start their loads. However, it must be remembered that generally increased locked-rotor torque is brought about by increased current which adds weight to the motor and associated equipment. Furthermore, there is never a need for additional assurance if the motor is correctly applied on the basis of starting as well as rated load conditions. It is better to use a larger motor to provide additional starting torque should a specific application require it rather than add a weight penalty to the entire system by building additional torque in all motors.

Basic Motor Constructions Involved

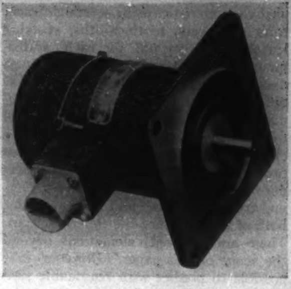

Figure 1. Aircraft motor, three-quarter horsepower, 10,800 rpm, 400 cycle, three phase

Open 400-cycle motors are most satisfactory for the majority of applications. Normally, they do not possess explosion-producing characteristics and can be ventilated with less complication and without excessive weight increases. Gasoline-pump motors will require an explosion-resisting construction. Some of these will operate submerged with their windings, bearings, and other vital parts directly exposed to the gasoline. A few totally enclosed intermittent motors may be required for engine nacelle or other locations saturated with oils or dirt.

Synchronous speeds of 24,000, 12,000, 8,000, 6,000, 4,800, and 4,000 rpm are possible from 2-, 4-, 6-, 8-, 10-, and 12-pole windings, respectively. The four-pole motor will be used almost exclusively. Generally a lighter-weight power unit can be obtained by gearing down to the desired speed rather than increasing the number of poles. Nevertheless six- and eight-pole motors will have a limited use for driving loads such as centrifugal fans and gasoline pumps because of the noise and lubrication problems associated with gears. Lighter-weight motors could be obtained by using two-pole windings, but the lack of suitable bearings capable of withstanding speed approaching 24,000 rpm without freezing at low temperatures prevents using them at this time.

Design Considerations

In designing 400-cycle aircraft motors it is necessary to correlate functions of five different kinds of engineering: namely, electrical, mechanical, thermal, air-flow and lubrication. Individually, these functions are complicated by the high-speed operation, better material utilization, and varying conditions in which the motors must operate. Correlation is particularly difficult, as the interrelation is such that any one function may affect any or all of the others. Usually the electrical studies are given first consideration, followed by fitting the other engineering factors around the basic electrical design. This is desirable, not because of a position of greater importance, but rather because the other functions to a large extent are determined by the electric output and losses.

ELECTRICAL DESIGN

Usually, the electrical design can be determined best by calculating performance characteristics using several different rotor diameters, tooth widths, stacking lengths, and so on, for each stator-punching diameter contemplated. By so doing the less important factors such as different amounts of primary copper, reduced iron thickness, modified ratios of tooth to core section, which affect the characteristics appreciably, are given proper consideration. Also, this procedure permits making allowances for thermal-transfer surfaces and air-flow paths, both of which reduce the electric output. These are involved calculations beyond the scope of this paper. However, it is possible to predict with reasonable simplicity approximate characteristics to be expected by considering what happens when a 60-cycle motor is operated on 400 cycles. The flux should be held at the design value, and if so maintained the applied voltage must be increased in the ratio of the frequency change. This is demonstrated by the commonly used flux formula:

$$\phi=\frac{E\times 10^8}{2.22\times f\times W_k\times C_1}$$

where

ϕ = flux in lines per square inch
E = applied voltage per phase
f = applied frequency
W_k = the winding constant
C_1 = primary conductors per phase

Raising the frequency causes the motor reactances to increase in proportion to the frequency change but does not affect the resistance values. Iron loss increases by an amount dependent upon the magnetic material used and the density at which it operates. Available data indicate that the increase is 12.5 times for high-grade silicon iron at a density of 95,000 lines per square inch. Windage losses vary as the cube of the speed. So-called stray losses resulting from tooth pulsations and similar losses vary in different designs but usually are about five per cent of the calculated electric output. Friction losses are small and can be neglected without appreciably affecting the over-all results.

Table I, column 1, contains design data and calculated characteristics for a typical 200-volt 60-cycle three-phase motor. Column 2 contains similar data for 400-cycle operation of the same motor. Column 3 contains similar 400-cycle data for the same motor with increased secondary resistance to obtain 160-per-cent starting torque. For the considerations tabulated in columns 1 and 2 rated load is arbitrarily placed at 50 per cent of the breakdown torque. For column 3 rated load is established such that the slip at this point does not exceed ten per cent of the synchronous speed and such that the breakdown and starting torques are at least 200 and 160 per cent of the full-load torque, respectively. The slip would exceed ten per cent if rated load were placed at 50 per cent of the breakdown torque.

From these data it is noted that rated output increases 9.3-fold when the 60-cycle motor without modification is operated on 400 cycles. The locked-rotor torque decreases to 23.5 per cent of the full-load torque which is far too low for most applications.

Table I. Design Data and Calculated Characteristics for Typical 200-Volt Three-Phase Motors

	Column		
	1	2	3
Design Data			
Applied volts per phase	115.5	770	770
Applied frequency, cycles	60	400	400
Primary resistance per phase, ohms	1.3	1.3	1.3
Secondary resistance per phase, ohms	2.2	2.2	13.95
Primary leakage reactance per phase, ohms	2.7	18	18
Secondary leakage reactance per phase, ohms	2.7	18	18
Magnetizing leakage reactance per phase, ohms	90	600	600
Iron loss, three-phase, watts	30	375	375
Windage loss, three-phase, at 1,800 rpm, watts	5.0	5.0	5.0
Stray-loss factor	0.95	0.95	0.95
Calculated Characteristics			
Full-load output, watts	1,125	10,430	8,200
Full-load speed, rpm	1,645	11,880	10,850
Full-load slip, per cent of synchronous speed	8.6	1.0	10
Full-load efficiency, per cent	81.0	79.5	73.8
Full-load power factor, per cent	90		89.5
Full-load torque, ounce-feet	77	99	85.0
Full-load loss, watts	265	2,720	2,900
Full-load primary I^2R loss, watts	79	156	105
Full-load secondary I^2R loss, watts	97	119	780
Full-load iron loss, watts	30	375	375
Full-load windage loss, watts	4	1,450	1,110
Full-load stray loss, watts	57	620	410
Breakdown torque, per cent of full load	200	200	231
Locked-rotor torque, per cent of full load	161	23.5	161
Locked-rotor input, watts	3,495	5,210	17,185
Locked-rotor primary I^2R loss, watts	1,335	1,805	1,510
Locked-rotor secondary I^2R loss, watts	2,130	3,040	15,330
Locked-rotor iron loss, watts	30	375	375

The rated output increases 7.3 times when the secondary resistance and rated loads are adjusted simultaneously to obtain 160-per-cent starting torque without exceeding ten-per-cent slip at rated load. Standstill and rated load losses increase 5- and 11-fold, respectively. Rotor losses at standstill increase 7.2 times which means that the heating rate of the rotor also increases. Hence the ability of the rotor to withstand locked-rotor conditions is materially reduced, particularly if the resistance increase is obtained by changing the amount of secondary material but not the material itself.

The power required to establish air motion through rotation of the rotor and fans normally constitutes the windage losses. Considering that the rotor portion is usually small, it appears that sufficient cooling exists on 400-cycle operation to permit continuous-rated-load operation. Whether or not this is true depends upon the arrangement of thermal-transfer surfaces and the flow of a cooling medium across these surfaces.

THERMAL AND AIR-FLOW DESIGN

The designs of thermal-transfer surfaces and air-flow paths are coincidental. Two basic arrangements are possible, one for double-end ventilation, the other for through ventilation. Most intermittent-rated motors and continuous-rated motors having large diameters and thin magnetic structures can be cooled successfully by double-end ventilation. When used, cool air brought in through suitable openings is directed such that it impinges on the ends of the windings and magnetic structures at high velocity. Heat generated internally must transfer to the exposed surfaces by conduction for dissipation. Usually these exposed surfaces are not adequate to dissipate the heat of continuous-rated motors having stacking lengths which permit minimum compactness and weight. In these, adequate ventilation can be obtained by conducting air through special openings in the magnetic structure. Best results are obtained by placing these openings, which should be designed for maximum air velocity and heat-transfer surface, where most of the heat is generated. Excellent air paths are obtained by pressing the stator windings back into the slots. This permits air flow directly over the stator and rotor windings as well as sections of the stator and rotor teeth. All of these have good transfer surfaces and are parts in which much of the heat is generated. Also, holes punched in the stator and rotor core sections serve as good air-flow paths.

MECHANICAL CONSTRUCTION

Several equally satisfactory but distinctly different mechanical constructions are possible. Usually that used is deter-

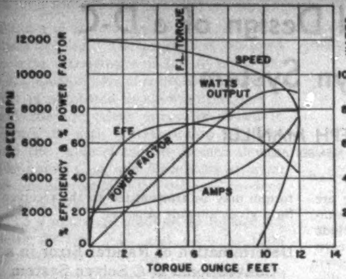

Figure 2. Characteristic curves for three-quarter-horsepower 10,800-rpm 400-cycle three-phase aircraft motor

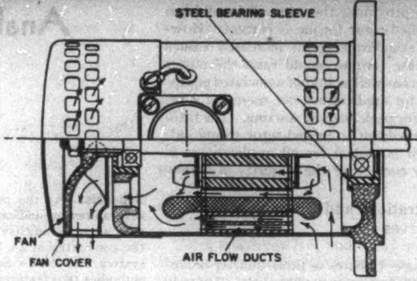

Figure 3. Section view of 400-cycle aircraft motor

mined by the basic requirements and other fundamentally extraneous considerations such as available manufacturing facilities, shop practices, and individual preferences. Such other considerations add to or detract from a design only to the extent of their influence on the making of individual parts or the assembly of these parts into the completed unit. Whether or not a design is satisfactory is determined wholly by weight considerations and ability to withstand burdens encountered over the range of operating conditions throughout its expected life, without destroying other essential characteristics. The most severe burdens are imposed by airplane vibrations. According to specifications vibrations up to 55 cycles per second with an excursion (double-amplitude) of $^1/_{16}$ inch may be expected.

The motor shells, end flanges, bearings, shafts, and a few other miscellaneous parts constitute the vital parts entering into the basic mechanical construction of most 400-cycle aircraft motors. Grease seals or other special features are required only for specific applications.

Comparable lightweight shells may be obtained either from low-specific-gravity materials such as aluminum or magnesium or from stronger high-specific-gravity materials such as steel but with the sections reduced. Steel shells with reduced sections permit a better over-all design, particularly in conventional constructions where accurate dimensions are necessary to maintain the radial location of stators slipped or pressed into the shells. These have the same coefficient of thermal expansion as that of the magnetic iron, and therefore the same accurate dimensions exist over the entire temperature range. Aluminum or magnesium shells have coefficients of thermal expansion greatly different from that of magnetic iron. Because of this, satisfactory dimensions at normal temperatures may not remain satisfactory and may cause failure through excessive stresses in the shells and magnetic structures when extreme temperatures below normal are approached.

Owing to limitations in manufacturing processes, the end flanges usually are made of low-specific-gravity materials. Internal rabbets should be used to eliminate failure from excessive stresses at low temperatures when the shells are made of steel.

At present, only ball bearings are satisfactory for the high-speed operation, but sleeve bearings with special lubrication may be used in the future. Bearings of the minimum size necessary for radial and thrust loads and the specified life should be used to prevent excessive torque for overcoming friction at low temperatures.

High-grade steel shafts with hardened extensions are required, particularly where pinions or splines are an integral part of the shaft extensions.

Lubrication

Suitable lubrication capable of withstanding high temperatures without freezing at low temperatures cannot be obtained. Those available lubricants capable of withstanding high temperatures freeze at about −30 degrees centigrade. Those satisfactory for low temperatures fail in a relatively few hours if operation is sustained at about 60 degrees centigrade or above. Lubricants do not remain frozen long after operation is started, and therefore they are objectionable only because of the added torque required to break the bearings loose. Generally, it is better to use the high-temperature lubricants and provide the additional torque required for starting.

Motor Characteristics

Specifications for the motor characteristics were established by considering many loads encountered aboard aircraft, together with anticipated variations caused by voltage and frequency fluctuations and changes in operating conditions. Both intermittent and continuous loads were scrutinized.

Intermittent motors are required principally to operate a variety of mechanisms such as wing flaps, cowl and oil cooler flaps, bomb-bay and turret doors, automatic temperature controls, and armament. However, some are required for driving hydraulic pumps, air compressors, or other miscellaneous applications. Fundamentally these are torque applications in which the power requirements vary almost continuously during the operating period.

Therefore the motors will be given a torque rating approximately equal to but not more than one third of the normal locked-rotor torque. In most of these applications peak torque requirements are considerably less than 200 per cent of the root-mean-square torque. The locked-rotor torques may decrease to about 200 per cent of their normal values under the most severe operating conditions which are brought about by a combination of minimum voltage, maximum frequency, and minimum temperature. Hence, 300-per-cent starting torque as established for the specifications is adequate for most applications. Usually there will be a surplus of torque as the factors entering into the most severe operating conditions do not occur simultaneously.

Continuous-rated motors are needed principally for driving fans, fuel pumps, hydraulic pumps, and air compressors, either directly or through gear reductions. Motorization of fans and fuel pumps of the centrifugal type, which are the devices "most used" usually, entails selecting ratings corresponding to the peak load requirements. Locked-rotor requirements are essentially those of the motor itself in the infrequent applications where gear reductions are used. Motorization of the other devices entails selecting ratings up to about ten times the normal or root-mean-square load if sufficient capacity for peak loads or starting is provided. The occasional or even frequent necessity of selecting ratings in excess of the normal load does not mean that the specifications should require greater breakdown and locked-rotor torques. Motor weights for these applications are the same, regardless of whether or not the ratings correspond to the normal or root-mean-square loads, providing the ratio of breakdown to locked-rotor torque is correct. However, standardizing on increased values for these torques would raise the motor weights as well as that of associated equipment for applications not requiring a reserve for peak loads or starting. The ratio of breakdown to locked-rotor torque, although not ideal for all applications, is nearly correct for the majority of them.

Illustrations and Characteristic Curves

Figure 1 shows a three-quarter-horsepower continuous 400-cycle 200-volt three-phase motor designed to operate in accordance with the requirements previously outlined. The weight of this motor is 3.4 pounds. It is about 40 per cent lighter than a d-c motor having the same horsepower and speed rating. Other 400-cycle and 24-volt d-c motors with corresponding ratings have about the same ratio of weight.

Figure 2 shows characteristic curves plotted from test data taken on the three-quarter-horsepower motor at normal voltage, frequency, altitude, and ambient temperature. Speeds, efficiencies, power factors, amperes, and watts output which are plotted against torques are included.

Figure 3 illustrates schematically the construction used for continuous-rated motors with outputs from one eighth to 25 horsepower. That used for intermittent-rated motors is similar except the ventilation ducts, overhung fans, and fan covers are omitted.

Major design features used in these motors are summarized as follows:

1. Magnetic structures fabricated from high-grade silicon steel with special anneal to permit high flux, good permeability, and low iron loss.

2. Insulation. Class-*B* material for insulating slots and for between-phase protection. Generally the stator windings are of heavy Formex-glass-covered wire to provide greater protection against heat shock. Stator core complete with windings impregnated with special moisture-resisting varnish.

3. Squirrel-cage-type rotors with brazed copper or brass windings. Protected with anticorrosion treatment.

4. Through ventilation in continuous-rated motors for minimum composition and weight. Double end-turn ventilation in intermittent-rated motors.

5. Shells made by expanding thin steel tubing to obtain light weight, rigid construction, and a temperature coefficient the same as that of the stator.

6. Magnesium or aluminum end shields for light weight.

7. Heat-treated alloy steel shafts for strength and dependability. Hardened shaft extensions with or without pinions or splines.

8. Double-shield-type permanently lubricated ball bearings housed in a steel insert in the end-shield castings to assure long life.

9. Protective finishes. Magnesium or aluminum castings treated against corrosion and primed with zinc chromate. Steel parts other than stator and rotor punchings cadmium- or zinc-plated. External parts except mounting surface have black wrinkle finish.

Conclusions

Present trends indicate an increasing demand for 400-cycle electric systems for both military and commercial airplanes. These trends are justified in part by the inherently light-weight rugged and dependable constructions possible in 400-cycle motors.

The information contained in the paper is that which seems most important. Many additional data have not been mentioned; however, it is hoped that the disclosures herein will assist in creating a better understanding of the motors and the performance to be expected from them.

Analysis and Design of a D-C Selsyn System

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Synopsis: At the present time there are several remote-indicating systems in common usage in industry. These types include the conventional a-c Selsyn, a-c Magnesyn system, and the d-c Selsyn. The d-c Selsyn embodies two features which present a distinct advantage in aircraft systems.

1. The system does not require an a-c source of power.

2. The system requires only three wires between transmitter and receiver, whereas all other types of systems require at least five wires leading from the transmitter to the receiver.

To offset somewhat these advantages, all d-c Selsyn systems now in operation have a very slight natural error which, although not important in some applications, becomes very undesirable in applications where a high degree of accuracy is required. In this paper the author presents a rigorous analysis of a conventional d-c Selsyn remote-indicating system. The first part of the analysis shows that a natural error exists in the system, which has a 60-degree cycle and which reaches a maximum value of 1.1 degrees. The error is zero at each 30-degree point and reaches a maximum almost midway between the 30-degree points. The natural error of the Selsyn system arises from the fact that the transmitter resistance is a linear function of the transmitter angle θ. This natural error may be overcome by designing a transmitter resistance in a nonlinear manner. The equation is developed for the necessary variation of the transmitter resistance with the transmitter angle. Furthermore, the shape of the toroid on which this resistor should be wound to give this desired variation, is derived therefrom. The paper further presents optimum values of resistances for both transmitter and receiver, in order that the greatest amount of torque may be transmitted to the receiver for a given amount of power.

Determination of Natural Error in a Conventional D-C Selsyn System

THE INVESTIGATION of the d-c Selsyn embodies two separate questions.

1. If no frictional error is assumed, what are the magnitudes and characteristics of natural errors which may exist in the instrument, and how may they be corrected?

2. For a given amount of power consumption how should the instrument be constructed to give best follower properties from transmitter to receiver; that is, for a given amount of friction, how can the frictional error be reduced to a minimum?

In analyzing the first question, we consider the conventional d-c Selsyn shown in Figure 1. The receiver coils AB, BC, and CA are wound with their magnetic axes at 120 degrees to each other and connected in a delta connection. Points A, B, and C are connected to points A', B', C', respectively, located at 120-degree intervals on the transmitter winding. The battery contacts D' and E' are on a diameter and may be moved at will.

Ideally, the direction of the resultant field in the receiver should move in exact coincidence with the angle θ in the transmitter. There is no a priori reason for supposing that this situation will exist. Actually, as we shall see, if the resistances in the transmitter are linear with the angle θ, the ideal situation does not exist. The amount of natural error introduced is determined in the following analysis:

We obtain first the current distribution in coils AB, BC, and CA when the contacts D' and E' are rotated θ degrees from A' as shown. $0 \leqq \theta \leqq 60$ degrees. The transmitter is assumed to have a re-

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sistance of R_1 ohms per degree, or 120 R_1 ohms per leg. The receiver is assumed to have a resistance of 120 R_2 ohms per leg. Each section of resistance in the circuit is numbered as shown in Figure 1, and the equivalent circuit is shown in Figure 2, with corresponding numbers and the value of each resistance shown. The points C, A, and B are marked, since we are interested in the voltages between these points.

To simplify the analysis we replace the delta sections 3-4-7 and 1-2-6 by their equivalent wye sections.

The transformation relationships which replace a delta system R_1-R_2-R_3 by a wye system r_1-r_2-r_3 are given by

$$\left.\begin{aligned} r_1 &= \frac{R_2R_3}{R_1+R_2+R_3} \\ r_2 &= \frac{R_1R_3}{R_1+R_2+R_3} \\ r_3 &= \frac{R_1R_2}{R_1+R_2+R_3} \end{aligned}\right\} \qquad (1)$$

The foregoing relationships leave the current and voltages at the three terminals unchanged.

Figure 3 shows the equivalent circuit after the transformation is made and the resistors 5 and 8 are combined. Values are shown. The resistance of the two parallel branches in Figure 3 are equal; hence half the total current flows in each branch. The system is further reduced in Figure 4, and we obtain for the total current

$$2i = \frac{60E(R_1+R_2)}{5{,}400R_1R_2+R_1^2(-\theta^2+60\theta+1{,}800)} \qquad (2)$$

The current in each branch is then

$$= \frac{30E(R_1+R_2)}{5{,}400R_1R_2+R_1^2(-\theta^2+60\theta+1{,}800)} \qquad (3)$$

Referring to Figure 3, we have the following voltages:

$$E_{CA} = i\left(\frac{120R_1R_2}{R_1+R_2}\right) = \frac{3{,}600Er}{(-\theta^2+60\theta+1{,}800)+5{,}400r} \qquad (4)$$

$$E_{AB} = -i\left(\frac{R_1R_2(120-\theta)}{R_1+R_2} - \frac{\theta R_1R_2}{R_1+R_2}\right) = \frac{-30Er(120-2\theta)}{(-\theta^2+60\theta+1{,}800)+5{,}400r} \qquad (5)$$

$$E_{BC} = -i\left(\frac{R_1R_2(60+\theta)}{R_1+R_2} - \frac{R_1R_2(60-\theta)}{R_1+R_2}\right) = -\frac{60Er\theta}{(-\theta^2+60\theta+1{,}800)+5{,}400r} \qquad (6)$$

where $r = R_2/R_1$. The currents in the coils are then, from Figure 1,

$$I_{CA} = -\frac{30E}{R_1}\left[\frac{1}{(-\theta^2+60\theta+1{,}800)+5{,}400r}\right] = K\phi_{CA} \qquad (7)$$

$$I_{AB} = -\frac{E}{2R_1}\left[\frac{60-\theta}{(-\theta^2+60\theta+1{,}800)+5{,}400r}\right] = K\phi_{AB} \qquad (8)$$

$$I_{BC} = -\frac{E}{2R_1}\left[\frac{\theta}{(-\theta^2+60\theta+1{,}800)+5{,}400r}\right] = K\phi_{BC} \qquad (9)$$

For a fixed number of turns, the magnetic fields due to each of the coils are proportional to the currents. Figure 5 shows the relative orientation of these fields when the current in each branch is positive. We denote the direction of the resultant field, ϕ, with the x axis by the angle θ'. When $\theta = 0$ we see from equations 7, 8, and 9 that ϕ_{CA} and ϕ_{AB} are equal in magnitude, and $\phi_{BC} = 0$. ϕ_{CA} is positive, and ϕ_{AB} is negative. Hence when $\theta = 0$, $\theta' = 0$.

To obtain the value of θ' for any value of θ, we denote the x and y components of the resultant flux by ϕ_x and ϕ_y. From Figure 5 we see that

$$\phi_x = \frac{\sqrt{3}}{2}(\phi_{CA}-\phi_{AB}) \qquad (10)$$

$$\phi_y = -\phi_{BC}+{}^1/_2(\phi_{CA}+\phi_{AB}) \qquad (11)$$

and

$$\tan\theta' = \frac{\phi_y}{\phi_x} \qquad (12)$$

Using equations 7, 8, and 9 and noting that the proportionality constant between flux and current is the same in every case, in conjunction with equations 10, 11, and 12, we obtain

$$\tan\theta' = \sqrt{3}\,\frac{\theta}{120-\theta} \qquad (13$$

It is important to note that equation 13, which shows how the receiver angle θ' varies with the transmitter angle θ, is independent of the values of the resistances used in the Selsyn. Hence changing the values of the resistances can in no way compensate for natural error in the instrument.

Figure 6 shows a plot of θ' versus θ for 60 degrees. Conditions repeat themselves every 60 degrees, of course, since at 60-degree intervals one battery contact is in coincidence with a coil terminal. We see from the figure that the receiver gives an exact indication of the transmitter every 30 degrees. On one side of this point the receiver lags and on the other side it leads the transmitter.

If we denote by β the difference of the receiver angle and the transmitter angle, we have

$$\beta = \theta-\theta' = \theta-\tan^{-1}\left(\frac{\theta\sqrt{3}}{120-\theta}\right) \qquad (14)$$

It readily may be shown that this error angle is symmetrical in magnitude about the point $\theta = 30$ degrees. Figure 7 shows a plot of β versus θ for $0 \leqq \theta \leqq 60$ degrees.

By differentiating equation 14 with respect to θ and setting the result equal

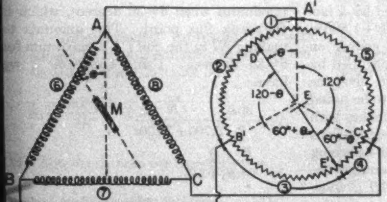


Figure 1 (left). D-c Selsyn transmitter and receiver

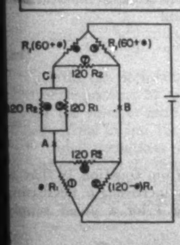


Figure 2 (lower left). Electric circuit of Figure 1

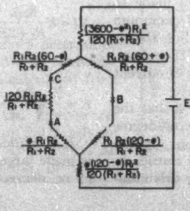
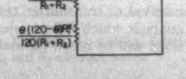


Figure 3 (center). Reduction of circuit in Figure 2

Figure 4 (below). Further reduction of circuit in Figure 2



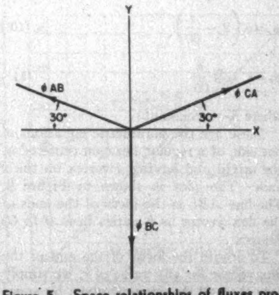


Figure 5. Space relationships of fluxes produced by receiver coils

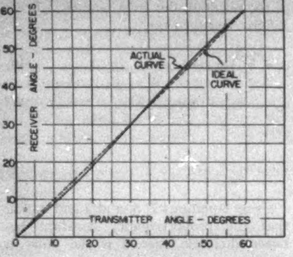


Figure 6. Variation of receiver angle with transmitter angle

to zero, we obtain the value of θ for which β is a maximum.* This gives values of $\theta = 13$ degrees 18 minutes and 46 degrees 42 minutes. The corresponding maximum values of β are 1 degree 6 minutes and -1 degree 6 minutes, respectively.

It is also of interest from a design standpoint to investigate the variation of the magnitude of the resultant field as θ is varied, since the friction error will depend on this magnitude. To do this we investigate first the case for $r \rightarrow \infty$, that is when the receiver resistance is many times larger than the transmitter resistance. Then $(-\theta^2+60\theta+1{,}800)$ is negligible compared to $5{,}400r$ in equations 7, 8, and 9. These equations become

$$I_{CA}=\frac{E}{180R_2} \tag{7'}$$

$$I_{AB}=\frac{-E(60-\theta)}{10{,}800R_2} \tag{8'}$$

$$I_{BC}=\frac{-E\theta}{10{,}800R_2} \tag{9'}$$

Figure 8 shows the current distribution in the coils for θ from 0 to 360 degrees. Equations 7, 8, and 9 are valid only from 0 to 60 degrees, but the rest of the cycle can readily be seen to be as shown. Substituting the foregoing values in equations 10 and 11, we obtain.

$$\phi_x=K\left(2-\frac{\theta}{60}\right) \tag{10'}$$

$$\phi_y=K\sqrt{3}\,\frac{\theta}{60} \tag{11'}$$

where K = constant.

These are the parametric equations of one side of a regular hexagon centered at the origin and having a vertex on the x axis. The plot is shown in Figure 9. The line ABC is the locus of the ends of the flux vector as θ varies from 0 to 60 degrees.

To obtain the locus of the end of the flux vector for any value of r, we simply note that all the currents given by equations 7′, 8′, and 9′ will be equal to the currents given by equations 7, 8, and 9 when the former are multiplied by a factor proportional to $1/(-\theta^2+60\theta+1{,}800+5{,}400r)$. Hence, the vectors ending on the line ABC need only be multiplied by the afore-mentioned factor to give the locus for any value of r. It is to be noted that the angle the flux vector makes with the x axis is θ', not θ, and hence equations 10′ and 11′ multiplied by the foregoing factor should be used to determine the locus. The lines $AB'C$ and $AB''C$ show the locus for $r=1$ and $r=0$, respectively. For comparison purposes, the maximum values in each case have been made to coincide. The actual value of maximum flux depends on R_1 and R_2, but this is discussed in the second part of the report. Figure 10 shows the variation of current in each coil for $r=1$.

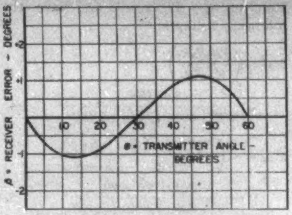


Figure 7. Natural error in Selsyn receiver

$$\beta=\tan^{-1}\left(\frac{\sqrt{3}\theta}{120-\theta}\right)-\theta$$

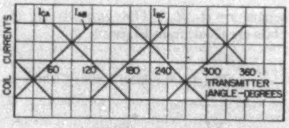


Figure 8. Current distribution in receiver coils, $r=R_2/R_1$

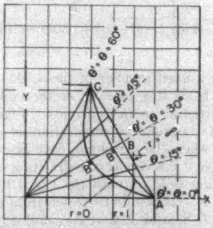


Figure 9. Loci of ends of flux vector for various resistance ratios

It may be seen from Figure 9 that the flux reaches a minimum every 60-degree interval of transmitter rotation. In the analysis which follows, design considerations will be based on making this minimum value of flux as large as possible for given power. As we shall see, this is not the same as making the maximum flux as large as possible.

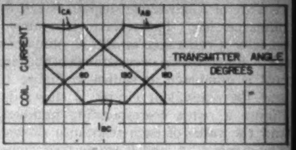


Figure 10. Current distribution in receiver coils for $R_2/R_1=1$

Optimum Transmitter and Receiver Resistances

For a given amount of power, and a given amount of space in which to wind the receiver coil, it is possible to determine optimum resistances for both transmitter and receiver and hence the wire size to be used in the receiver. It is also possible to determine the best size of receiver coil, consistent with space limitations.

Let us assume that the coil is to have the dimensions shown in Figure 11.

l = length of one turn
a = cross-section area of coil
N = number turns on one coil
A = cross-section area of wire

We then have

$$120R_2=\text{total resistance of coil}=\frac{\rho l N}{A} \tag{15}$$

$$NA=\alpha a$$

where α is a spacing factor. (16)

$$\alpha=0.91$$

We wish to make the resultant flux a maximum when $\theta=30$ degrees, which is the weak flux point. This amounts to making NI in the coil CA a maximum for $\theta=30$ degrees. Using equation 7, we have

$$\begin{aligned} NI&=\frac{30E}{R_1}\,\frac{N}{2{,}700+5{,}400r}\\ &=\frac{E}{90}\,\frac{N}{R_1+2R_2} \end{aligned} \tag{17}$$

Using equations 15 and 16, we eliminate N and obtain

$$NI=K\frac{R_2^{1/2}}{R_1+2R_2} \tag{18}$$

where

$$K=\frac{E}{45}\sqrt{\frac{30\alpha a}{\rho l}}$$

It is evident from equation 18 that K is made large by increasing a, decreasing ρ, or decreasing l for a given supply

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* See Appendix I.

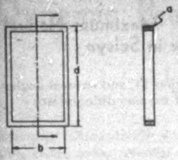

Figure 11. Coil dimensions

l = mean length
One turn
$= 2(d+b)$

voltage. It is not advisable to decrease *l*, since the enclosed area of the coil is proportional to torque for given *NI*. However, for best results, *a* should be made as large as possible and ρ as low as possible, that is, low-resistivity material should be used.

The maximum power consumed in the circuit is given by

$$P=\frac{E^2}{R_{\min}}$$

where $R_{\min}$ is the least value of resistance between battery terminals. From Figure 4 we see that

$$R_{\min}=\frac{30R_1}{R_1+R_2}(R_1+3R_2)$$

and since

$$P=\frac{E^2}{30}\,\frac{R_1+R_2}{R_1(R_1+3R_2)} \tag{19}$$

from which

$$R_2=\frac{R_1\left(1-\dfrac{30P}{E^2}R_1\right)}{\left(\dfrac{90P}{E^2}R_1-1\right)} \tag{20}$$

Substituting value of R_2 from 20 in equation 18, we obtain

$$NI=K\frac{(-3K'^2R_1^2+4K'R_1-1)^{1/2}}{R_1^{1/2}(K'R_1+1)};\quad K'=\frac{30P}{E^2} \tag{21}$$

By differentiating expression 21 with respect to R_1 and equating result to zero, we obtain, for maximum *NI**

$$R_1=\frac{1+2\sqrt{2}}{7K'}=0.547\frac{E^2}{30P} \tag{22}$$

$$120R_1=\text{resistance per leg}=2.19\frac{E^2}{P}$$

and from equation 20

$$R_2=R_1\frac{(3-\sqrt{2})}{(3\sqrt{2}-2)}=\frac{1}{\sqrt{2}}R_1 \tag{23}$$

With the optimum values determined from equations 22 and 23, the size wire for the receiver may be calculated from equations 15 and 16.

Small variations of the receiver resistance from the optimum value will not affect the performance appreciably, although power consumption, of course, will change. This may be seen by writing equation 18 in the form:

$$NI=\frac{K}{R_1^{1/2}}\;\frac{r^{1/2}}{(1+2r)} \tag{18'}$$

Equation 18 is plotted in Figure 12 for both R_1 constant and R_2 constant. It may be seen that the variation of *NI* with R_2 is small, whereas the variation with R_1 is greater, in the region of $r=\dfrac{1}{\sqrt{2}}$.

Design equations based on making the flux a maximum in the strongest point, that is, when $\theta=0$, lead to somewhat different equations. Analysis similar to the foregoing yields the following results:

$$120R=\text{resistance per leg}=2.30\frac{E^2}{P} \tag{22'}$$

$$R_2=\frac{R_1}{\sqrt{3}} \tag{23'}$$

For best performance, equations 22 and 23, not 22′ and 23′, should be used.

Correction of Natural Error in Selsyn System

In the first part of this report it was found that the error is zero in the receiver when the transmitter angle θ (see Figure 1) is 0, 30, 60 degrees, and so forth. Since one of the brushes is in contact with a terminal every 60 degrees, it is obvious that any nonlinear resistance must be symmetrical on either side of every 0, 60, 120 degrees, and so forth. Furthermore, since the natural error for a linear resistance is symmetrical and of opposite sign on either side of every 30-degree point, we may assume that the nonlinear resistance should be symmetrical on either side of 0, 30, 60 degrees, and so on.

The foregoing considerations reduce the problem to one of finding the deviation from linearity for the region from 0 to 30 degrees, making the deviation from 30 to 60 degrees symmetrical about the 30-degree point and of opposite sign, then repeating the cycle every 60 degrees.

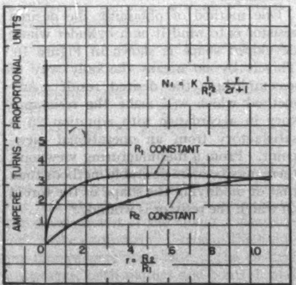

Figure 12. Variation of ampere turns with R_1 and R_2 constant power

Referring to Figure 1, we let the resistance of each transmitter leg be $120R_1$, and the resistance of each receiver leg $120R_2$, as before. For $\theta \leqslant 30$ degrees, let the resistance of that portion of the winding marked ① be equal to αR_1. The problem now resolves itself into one of finding α as a function of θ such that the error shall be zero for all values of θ from zero to 30 degrees.

Remembering the symmetry which we have noted, the values of the resistances ① to ⑤ of the transmitter then must be

① $=\alpha R_1$
② $=(120-\alpha)R_1$
③ $=(60+\alpha)R_1$
④ $=(60-\alpha)R_1$
⑤ $=120R_1$

Referring to Figure 2, we see that the afore-mentioned resistances are exactly the same as those shown in Figure 2, with α substituted for θ. In our present situation, then, it is obvious that the receiver angle θ', will be given by equation 13, with α substituted for θ, or

$$\tan\theta'=\frac{\sqrt{3}\alpha}{120-\alpha} \tag{24}$$

In order to have zero error, $\theta=\theta'$, and $\tan\theta=\sqrt{3}\alpha/(120-\alpha)$.

Solving for α, we obtain

$$\alpha=\frac{120\tan\theta}{\sqrt{3}+\tan\theta} \tag{25}$$

This gives the necessary variation of α with θ for zero error and hence the variation of resistance with θ, since the resistance of segment ① is αR_1.

Figure 13 shows the variation of α with θ, along with the linear variation, so that the deviation may be noted.

It is to be especially noted that the variation of α with θ for zero error is independent of the receiver resistance and hence will work for all receivers or paralleled receivers.

To obtain the shape of the developed cylinder which will give a resistance in accordance with equation 25, we refer to Figure 14. *OABC* represents 30 degrees

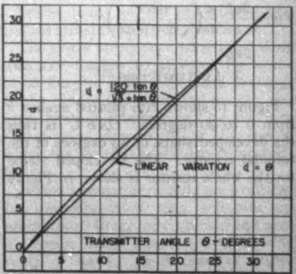

Figure 13. Variation of modification factor with transmitter angle θ

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* See Appendix II.

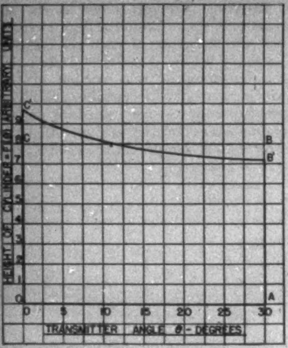

Figure 14. $F(\theta)$ for 0 degrees $\leq\theta\leq$ 30 degrees

of the developed cylinder for a linear resistor. $OAB'C'$ represents the shape of 30 degrees of the developed cylinder for the nonlinear resistor.

Let us denote the equation of $C'B'$ as $F(\theta)$. For a particular value of θ, the ratio of the nonlinear resistance to the linear resistance will be equal to the ratio of the area beneath the curve $C'B'$ to the area beneath the curve CB. This ratio is obtained from the equations of the two curves in Figure 13. Hence we have

$$\frac{\int_0^\theta F(\theta)d\theta}{L\theta}=\frac{120\tan\theta}{\sqrt{3}+\tan\theta}\cdot\frac{\pi}{180\,\theta}$$

$$=\frac{2\pi}{3\theta}\,\frac{\tan\theta}{\sqrt{3}+\tan\theta}$$

where θ is expressed in radians, and $L=OC$ in Figure 15.

If we solve for the numerator in the lefthand side,

$$\int_0^\theta F(\theta)d\theta=\frac{2\pi L}{3}\,\frac{\tan\theta}{\sqrt{3}+\tan\theta} \tag{26}$$

If we differentiate both sides with respect to θ,

$$F(\theta)=\frac{2\pi L}{3}\,\frac{d}{d\theta}\left(\frac{\tan\theta}{\sqrt{3}+\tan\theta}\right)$$

$$=\frac{2\pi L}{3}\,\frac{1}{(\sqrt{3}\cos\theta+\sin\theta)^2} \tag{27}$$

Figure 15 shows $F(\theta)$ plotted against θ from 0 to 30 degrees. $OAB'C'$ is thus the developed shape of 30 degrees of the toroidal resistor. The developed shape for the whole resistor is shown in Figure 15.

Conclusions

In a d-c Selsyn a natural-error cycle exists which has a 60-degree period. The error is positive for 30 degrees and negative for 30 degrees, reaching a maximum of 1 degree 6 minutes at 13 degrees 18 minutes and 46 degrees 42 minutes on the transmitter.

Design equations to give maximum flux in receiver for a given voltage and power are given by

$$\text{Transmitter resistance}=2.19\frac{E^2}{P}\text{ ohms per leg}=R_T \tag{22}$$

$$\text{Receiver resistance}=\frac{1}{\sqrt{2}}R_T\text{ ohms per leg} \tag{23}$$

Furthermore, the cross-sectional area of the receiver coil should be as large as is practical, and the resistivity of the receiver coil as low as possible.

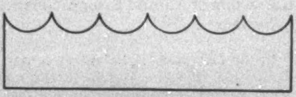

Figure 15. Developed shape of cylinder on which transmitter-resistor may be wound in order to produce zero error

The material and design dimensions of the transmitter coil are immaterial insofar as flux properties are concerned.

The natural error of a d-c Selsyn system may be eliminated completely by winding the transmitter resistance in a nonlinear manner.

The necessary variation of resistance with transmitter angle to give zero error is independent of receiver resistance. This correction for natural error may be attained for all possible loads on the transmitter.

One method of obtaining the desired resistor is to wind it on a cylinder whose developed shape is shown in Figure 16. This is by no means the only way of accomplishing the desired result. Any method which will make the resistance vary in accordance with equation 25 is satisfactory from an operational viewpoint. From a manufacturing viewpoint there may be more desirable methods than that of modifying the shape of the toroid on which the resistor is wound.

Appendix I. Maximum Natural Error in Selsyn

If we use equation 14, and express angles in radians, so that we may differentiate

$$\beta=\frac{\theta}{57.3}-\tan^{-1}\frac{\sqrt{3}\theta}{120-\theta}$$

$$\frac{d\beta}{d\theta}=\frac{1}{57.3}-\frac{1}{1+\left(\frac{\sqrt{3}\theta}{120-\theta}\right)^2}\times\frac{(120-\theta)\sqrt{3}+\sqrt{3}\theta}{(120-\theta)^2}$$

$$=\frac{1}{57.3}-\frac{120\sqrt{3}}{(120^2-240\theta+4\theta^2)}=0$$

for maximum β

If we solve,

$$\left(\frac{\theta}{60}\right)^2+\left(\frac{\theta}{60}\right)+1=\frac{57.3\sqrt{3}}{120}=0.828$$

$$\left(\frac{\theta}{60}\right)^2+\left(\frac{\theta}{60}\right)+0.172=0;$$

$$\frac{\theta}{60}=\frac{1\pm\sqrt{1-0.69}}{2}=0.778\text{ or }0.222$$

$$\theta=13.3°,\ 46.7°$$

Appendix II. Conditions for Maximum *NI* in Receiver

If we use equation 21,

$$NI=K\frac{\Delta}{R_1^{1/2}(K'R_1+1)}$$

where

$$\Delta=[-3K'^2R_1^2+4K'R_1-1]^{1/2}$$

$$\frac{d(NI)}{dR_1}=0$$

$$=K\left[\frac{R_1^{1/2}(K'R_1+1)\cdot{}^1\!/\!_2\Delta^{-1}\times(-6K'^2R_1+4K')-\Delta\{R_1^{1/2}K'+R_1^{-1/2}(K'R_1+1)\}}{R_1(K'R_1+1)^2}\right]$$

Setting numerator equal to zero, we have

$$R_1(K'R_1+1)(-6K'^2R_1+4K')=(-3K'^2R_1^2+4K'R_1-1)(R_1K'+K'R_1+1)$$

If we multiply and separate powers of R_1,

$$-7K'^2R_1^2+2K'R_1+1=0$$

$$R_1=\frac{1}{K'}\,\frac{-2\pm\sqrt{4+28}}{14}=\frac{1}{K'}\,\frac{1\pm\sqrt{8}}{7}$$

If we discard negative values of R_1, as meaningless,

$$R_1=\frac{1+2\sqrt{2}}{7K'}=\frac{0.547}{K'}$$

Dynamic Braking With Traction Motors

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Synopsis: Retardation with traction motors, either independently or as an adjunct to mechanical braking, has been utilized in various forms on practically all types of electric vehicles from battery trucks to main-line locomotives. In some cases, it is used only to maintain uniform speeds on long grades and in others to make regular service stops. Although the general principles are nearly as old as the electric-traction industry itself, in recent years numerous refinements have greatly extended the usefulness of dynamic braking by affording improved performance, additional safety, and simplification of mechanical-braking systems. This paper discusses the various means by which favorable results have been accomplished, with a minimum amount of additional electric equipment.

The Origins of Dynamic Braking

FROM THE STANDPOINT of basic terminology, "dynamic braking" could cover any and all forms of retardation created by an electric motor acting as a generator. However, in traction parlance, the term is recognized as referring to a system of dissipating the generated energy in resistors carried on the vehicle, as distinguished from "regenerative braking" where the generated energy is returned to the power system, necessarily at line voltage.

In the early days when streetcar speeds and weights outgrew the hand brake, air brakes had not been developed for small equipments, and the need for some form of power-operated braking apparatus led to the application of several kinds of "magnetic" and "dynamic" brakes. The traction motors were used to generate on a closed resistor circuit, the dynamic current producing retardation in the motors themselves and also energizing magnetic track shoes and applying wheel brakes, both at the same time. For standing on grades, the magnetic shoes were energized by line current, becoming a direct "electric" brake.

It was known that a series motor, rotated backwards and short-circuited on itself, would generate current and "buck," as a result of building up circulating current from the residual field magnetism retained in the iron after operating with power. By reversing the field connections with reference to the armature, the motor would "buck" without changing the direction of rotation. Two motors permanently connected in parallel provide a loop circuit which permits both to build up as generators. This action is experienced when one is attempting to tow a four-motor car backwards without first opening the paralleling circuit between motors.

Conventional four-motor equipments can be stopped in emergency, without power, simply by reversing the motors. The result is a cumulative generating effect which builds up suddenly, after some delay, the current and voltage rising to excessive peaks. Before the car comes to a stop, frequently with a series of jerks, one motor usually will slip and start running backwards, being driven as a motor by the other machine, which continues to generate at a diminishing rate until the car slows down to a creeping speed.

In all of the early forms the traction motors were reversed in changing from power to brake operation and were operated all in parallel on a single load circuit consisting of brake magnet coils and variable resistors. A stabilizing connection was made, paralleling the motor fields to equalize the load on all armatures.

Later, additional stability was secured by cross-connecting pairs of armatures and fields, in effect producing separate excitation and better inherent equalizing of the load.

Typical forms of magnet-operated wheel and track brake shoes are illustrated in Figure 1. It is interesting to note that many of the operating advantages claimed for these equipments are as fully attractive today as they were when advocated 40 years ago. These may be summarized as follows:

1. Regulated braking independent of line power.
2. Safety in operation, with an additional powerful braking system.
3. Control of speed down long grades.
4. Use of braking energy for car heating.
5. Braking rates in excess of adhesion limits.
6. Prevention of skidding with locked wheels.

These pioneer systems were very effective and were used extensively abroad but fell into disuse in this country with the development of the simple "straight-air" brake equipment. Some of the limiting factors were the abuse of the electric apparatus, both motors and control, and the excessive weight and mechanical maintenance of magnetic-shoe devices. As a result, there was little advance in the art of "dynamic" braking over a period of several years.

Design and Performance of Motors Used as Series Generators

One of the major factors leading to the revival and extensive use of dynamic braking in recent years has been the improvement in commutating characteristics and overload capacities in the modern lines of traction motors. Normal proportioning of the operating characteristics found in passenger vehicles involve a balancing speed of at least twice the speed at which the motors have full voltage applied at full load. To produce a full-load braking rate in the balancing-speed zone, it is obvious that the generated voltage may be double the rated line voltage. Motors capable of satisfactory commutation under these conditions are in common use. To provide for braking at occasional excessive speeds, it is sometimes desirable to initiate the braking action with the fields shunted so as to limit the voltage to a safe maximum, accepting a reduced braking rate in the high-speed zone.

Inherent stability by inductance and also generous commutating and insulation factors are essential design characteristics.

In the case of four-motor equipments, the motors frequently are wound for half voltage and connected permanently two in series. In the limited space available, it is practicable to build low-voltage commutators and brush rigging with an increased margin for overvoltage operation, thus extending the speed range for full-load dynamic-brake operation.

Motor applications for dynamic braking must take into account grade conditions amounting to 20 pounds of retarding force per ton of total train weight for each one per cent of downgrade, in addition to the stored kinetic energy requiring approximately 100 pounds per ton of retarding force for each unit of miles per hour per second braking rate desired. The actual braking effort required of the motor is reduced by the friction and windage drag of the vehicle. Obviously, the total must be kept within the recognized adhesion limits of the motorized axles and the rated capacity of the motors.

The motor rating must be selected with sufficient margin to perform the combined duty of acceleration and braking. In the case of self-ventilated motors, the extra heating is minimized by the fact that it takes place mostly at high speeds where the ventilating system is most effective.

Where two motor circuits are available for interconnection, they will pick up generating voltage very quickly and give a prompt brake response over a wide range of speed. In the case of single-motor equipments, the response is not so prompt, and field flashing is desirable.

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The amount of exciting current normally is not more than ten per cent of full load, and it can be removed as soon as braking is initiated, so that the added power requirement is negligible.

The typical behavior of a motor in building up the braking load is illustrated by the oscillograph record shown in Figure 2.

Dynamic-Brake-Control Characteristics

Another factor in the rapid extension of the use of dynamic braking has been the development of simplified control systems for initiating and regulating the braking load.

By adopting a permanent connection for each pair of motors whereby in both power and brake the relations of armature and field are interchanged with reference to the line, the series and parallel connections for power and the parallel connection with cross-connected fields for braking can be obtained with a minimum of switching equipment. Furthermore, the transfer from power to brake can be made without operating the reversing devices, and practically all of the switching and resistor equipment required for acceleration also can be used in brake regulation. Figure 3 illustrates in simplified form the relative arrangement of motor and resistor circuits.

In addition to the accelerating resistor steps in each motor circuit which are kept balanced in value at all times, the brake circuit is completed through a common loop which carries the combined current from both motors and includes resistor steps of a value which essentially doubles the total effective resistance in each motor circuit. This total amount is determined by the excess voltage to be absorbed when applying the brake at maximum speed.

In order to secure prompt build-up of the brake without separate excitation, it is customary to close the brake loop circuit through a high resistance each time power is shut off. This recaptures the residual volts before the flux has collapsed and immediately circulates a braking current of low value, not enough to cause any appreciable retarding effect, but sufficient to keep the motors in a responsive state. Brake application then is uniformly prompt, depending on the rate at which resistance is reduced in the loop circuit. This is known as the "spotting" system.

The basic cross-connection of motors, whereby each becomes separately excited, not only produces inherent stability and load equalization, but also avoids skidding, because any tendency on the part of one motor to lower its speed immediately reduces the field of the other motor. This in turn reduces the voltage being applied to the motor which has attempted to slow down by creeping. There is no sudden or complete loss of retardation.

The regulation of braking rates may be controlled either manually or automatically. Locomotives with varying train weights and grade conditions normally would be manually operated and the brake used principally for holding a controlled speed on long grades. Where grade or slowdown brake requirements exceed the locomotive adhesion limits, dynamic braking must be supplemented by the train brakes, and some provision is desirable to prevent applying the air brakes on the locomotive as long as the dynamic brake is operating.

Passenger vehicles in frequent-stop service require uniform braking, sometimes at relatively high rates, all of which is best accomplished with automatic current regulation. The operator's attention then is concentrated on the selection of the desired braking rate, no particular skill being required to produce a smooth stop.

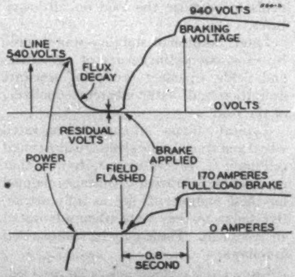

Figure 2. Motor voltage and current record of the transfer from power to brake operation

The minimum speed to which full-load braking can be maintained is determined by the internal resistance of the motor added to the resistance of the cables and switching equipment. For the average urban transit vehicle, this speed is two to three miles per hour, below which the brake fades out and disappears.

Selection of the total number of braking notches is governed by the same general factors as the selection of acceleration notches. Passenger comfort, slope of the motor saturation curve, maximum speed of application, bunching of slack in trains, adhesion limits, and minimum fade-out speed all require consideration. A study of Figure 4 shows that at high speeds the braking curves are very steep and can be spaced rather widely apart, whereas at low speeds they are relatively flat and require close spacing to hold the current increments within uniform acceptable limits. Obviously, the higher the braking rate, the greater the number of notches required.

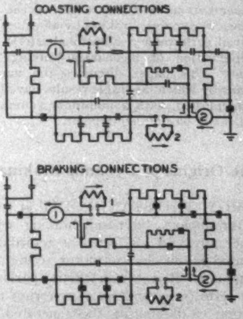

Figure 3. Standard motor circuit connections for power and brake operation, with pre-excitation by "spotting" in the coasting position

Many applications are based on an average braking load somewhat less than the full accelerating load and require the same number of notches for each, even though the speed range in braking may be twice the range over which the accelerating equipment is in operation. The apparatus required to control the braking, in excess of that used in acceleration, thus is held to a minimum.

Each application requires a careful study of the switching system and resistor-step values, if they are to be used to the best advantage in both power and brake operation.

Figure 1. The Newell streetcar brake of the year 1900, comprising combined track and wheel-brake shoes, both energized with current generated by the traction motors

Advantages and Economies in Operation

In making the fundamental decision as to whether or not dynamic braking should be included in any given application, the following benefits are to be considered:

1. Safety in operation, as provided by an effective brake system, in addition to the regular mechanical brakes.
2. The use of accelerating and braking resistor losses for heating the vehicle.
3. Simplification of the mechanical brake equipment.
4. A marked reduction in wear on brake shoes and wheel rims or brake drums, with less frequent adjustment and replacement.
5. Minimized skidding and side slipping under adverse rail or street conditions.
6. Better feeling of security on the part of operators.
7. Automatic regulation and graduation of the brake in making service stops.

Typical Applications and Results

The PCC Car

No dynamic-brake system has shown such phenomenal benefits as the equipment which is standard on all PCC streetcars, of which there are nearly 3,000 in operation and on order. Without such a system, the cushioned-wheel type of truck could not have been used because of the excessive heating and the massive brake rigging which would have been required to produce the high deceleration rates with mechanical brakes alone. Being independent of line power, this equipment is extremely reliable and makes possible the high schedule speeds for which the vehicle is designed.

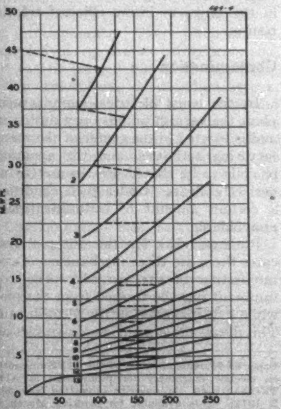

Figure 4. Typical dynamic-brake notching curves for service stops from maximum speed to three miles per hour

The converted energy of retardation, introduced into the ventilating system in the form of heat, provides adequate car heating without the use of supplemental heaters, in all except the most severe winter conditions.

A simple form of air brake and a magnet track brake supplement the dynamic brake. The latter normally is required only in emergency, and the light duty on the air-brake shoes has extended the life of brake shoes and the adjustment period to at least 15 times that for older types of streetcars.

The multinotch control developed for these cars produces exceedingly smooth brake performance, and deceleration rates as high as four miles per hour per second can be obtained with comfort. The "spotting" system of recapturing residual voltage for quick brake response is used to position the control in proportion to speed during coasting, so that the correct resistance value always is available for immediate full-brake application. The regulation is automatic with a wide selection of rates.

Trolley Coaches

With the prevailing tendencies toward high schedule speed, the necessary braking rates long since have exceeded the limitations of brake-drum and wheel-rim temperatures. Of the more than 3,500 trolley coaches in the United States, nearly half have included some form of dynamic or combined dynamic and regenerative braking. The results in operation compare favorably with those obtained on PCC cars, with an important increase in dependability and safety on slippery pavements. There has been a reduction in brake-block and brake-drum maintenance to about one fourth of that which existed when all braking is done mechanically.

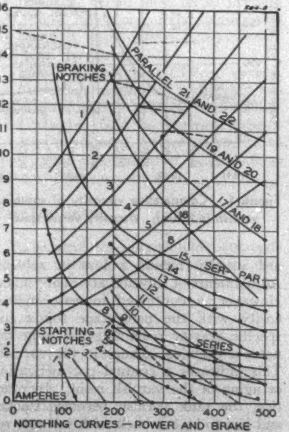

Figure 5. Complete locomotive starting and braking notching curves, with several brake-holding positions

Haulage Locomotives

Braking conditions on material-handling systems, particularly in underground mining, are more severe than in any other branch of the traction industry. Grade and track conditions are extremely variable, and in many cases the cars have no power-brake equipment, all braking duty being concentrated on the locomotive itself. The advantages of a dynamic brake, supplementing the mechanical wheel-brake system, in safety and dependability have been demonstrated repeatedly. In open-pit mining, long grades frequently are encountered, and dynamic braking can be proportioned to absorb at least 50 per cent of the total braking effort required, with a corresponding increase in brake-shoe and wheel life on cars and locomotives.

Another notable application is the use of a dynamic holding brake on Diesel-electric main-line locomotives in high-speed mountain grade service.

Figure 5 shows the combined acceleration and braking performance curves for a haulage locomotive with several manually selected brake-holding notches.

Rapid Transit

In this field dynamic braking has not yet found any general application. However, it is reasonable to anticipate that future extensions will follow the trend toward faster schedules and higher braking rates. The problems associated with brake-shoe dust, wheel wear, and skid flats will become increasingly critical, and dynamic braking will have definite advantages in this respect. Furthermore, uniform braking on all wheels in the train will be assured.

Summary

The many proved benefits to be realized in the use of dynamic-braking systems bear a most favorable proportion to the nominal amount of additional apparatus involved. They are applicable to practically all branches of the land-transportation industry.

Control of Electrical-Insulating Varnishes

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Synopsis: Varnish treatment of electrical equipment is an important step in its manufacture. Varnish coatings protect apparatus from moisture and dirt and maintain the high electrical-insulating level required for insulation. The quality of the varnish film deposited depends upon the condition of the varnish in the processing tanks. Thickness of deposited varnish films varies with viscosity and body. Heavy films interfere with armature-coil sizes and make problems of heat transfer in field coils and magnet coils more difficult. Thin films give inadequate protection from moisture and dirt. Conducting contaminating materials are introduced into the tanks from rehabilitated apparatus and manufacturing atmosphere. These indicate that close control of tank varnish is necessary for consistently high quality of apparatus treated. Methods of control are discussed which include both laboratory tests of the varnish and physical tests which can be concluded at the tank. A system of daily inspection of tanks for proper quality and daily adjustments before use is described. Dielectric properties of the varnish film and the liquid varnish and periodic chemical analysis of samples from each tank reveal the condition of the varnish. A system of portable cold pressure filtering for removing much of the contamination present is described. It should be recognized by the electrical industry that insulating varnishes are complex chemical mixtures, and care should be maintained in their use. It is important that they be under the control and supervision of persons with the proper training and experience. Constant quality control is necessary for satisfactory results.

THE PROTECTIVE CAPACITY of varnish on electric equipment depends upon the quality of the varnish in which the apparatus is treated. Proper maintenance of varnish requires consideration of many factors. Modern synthetic varnishes are a complex combination of resins and solvents which must be properly controlled. The quality of the varnish film depends on many factors including the viscosity–body relationship, the degree of polymerization of the resins, chemical composition of the resin, and the purity of the film. There is a tendency for insulating varnish to become contaminated with various foreign materials in the course of its use. Contaminants seriously impair the insulation value of the varnish and lower the reliability of the electrical equipment treated.

Certain difficulties in manufacture may be overcome by proper control. For example, certain coils treated in varnish of excessive viscosity may result in oversize conditions due to deposition of heavy varnish films. Improper varnish treatments may cause unduly high temperature rises. Troublesome effects of poor varnish treatment may become apparent during factory tests or when the machine is in service.

Chemical Changes in Varnish

Body, viscosity, and specific gravity of varnishes are interdependent. Body is the per cent nonvolatile material (resin, drying oil, plasticizer) in the varnish. Deposition of the nonvolatile material from the solvent forms the varnish film.

Viscosity is a measure of the resistance of a fluid to flow. Viscosity is dependent upon the body of varnish and also upon the degree of polymerization—that is, the average chain length of varnish resin molecules. Polymerization in turn is a factor in the aging of varnish resins. Specific gravity is a measure of the amount of solid material in a given solvent. The amounts of solvent and solids, and the condition of resin may be interpreted by means of these tests.

For example, an increase in viscosity and specific gravity from a given standard usually means a loss in solvent. Adjustments of solvents are easily made. However, a continued increase in viscosity with the percentage solids and specific gravity remaining the same denotes a chemical change in the varnish. This indicates a gradual polymerization or aging of the varnish resin. In practice, the tank varnish becomes thicker and has to be cut back with solvents repeatedly to insure smooth coating. The percentage solids soon becomes low as a result of addition of solvents, and a thin varnish film with poor physical properties is deposited, which does not impart adequate insulation protection.

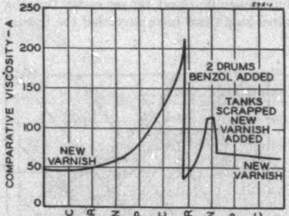

Figure 1. Comparative viscosity of synthetic varnish in toluol, viscosity versus time

Figure 1 gives comparative viscosity of a tank of synthetic varnish over a period of 29 months. Comparative viscosity is a method of comparing the viscosity of a varnish at a particular body to a viscosity at a reasonable standard reference body for the same varnish. Gradual rises in the curve with time show an increase in the degree of polymerization or aging of the resin. Eventually, the physical properties of the film deposited become so poor that the varnish must be scrapped. If one refers to the curve, 50 is the index for varnish in good condition. After nine months there is a steady rise in comparative viscosity to 130 (14 months after start). At this time the physical properties are definitely below standard.

If viscosity and specific gravity of tank varnish are allowed to increase owing to solvent losses without adjusting to a given standard, a thicker varnish coat is deposited. Thick coatings on armature coils result in difficulty in winding in slots because of their being oversize. Too heavy coats deposited on field coils and magnet coils decrease the rate of heat transfer and result in higher temperature rises. Table I gives the thermal conductivity of a magnet coil in degrees rise per watt after successive coats of varnish.

In general, film thickness is dependent upon viscosity, whether viscosity is adjusted by solvent or by heating the varnish. Figure 2 gives varnish build-up versus viscosity of a synthetic varnish (in toluol solvent) deposited on copper, paper, and fiber glass. Note that on glass a rise in viscosity from 35 seconds to 100 seconds deposits a film 30 per cent thicker.

It is apparent that a proper body–viscosity relationship must be maintained in the tanks to insure efficient treating results.

Contamination

In the usual electrical-manufacturing plant the varnish tank is open during use and is located in the center of the manufacturing activities, and the apparatus or coils to be coated are themselves not perfectly clean. Under such conditions a certain amount of contamination is unavoidable.

Previous work by the authors[1] indicates there are three mechanisms of contamination of the varnish. The contaminant may be washed from the piece while it is immersed in the varnish tank. This means the suspension of particles of a

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The authors are indebted to T. J. Schrimser, L. R. Hill, M. W. Rider, P. E. Demmler, and associates, for advice on test methods and removal of contaminants.

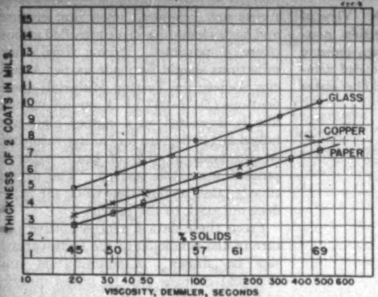


Figure 2 (left). Synthetic alkyd varnish, toluol thinner, build-up of film versus viscosity

All samples drained at 28 degrees centigrade

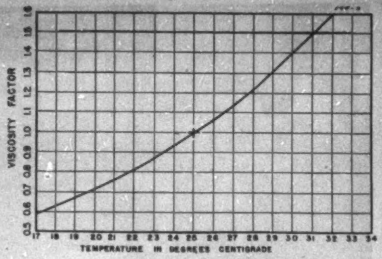


Figure 3 (right). Correction of viscosity to a base temperature of 25 degrees centigrade

Viscosity at temperature X viscosity factor = viscosity at 25 C

particularly troublesome nature in the varnish. For example, when rehabilitated armatures are being processed, some of the dust and dirt accumulated in field industrial use is washed into the varnish tanks on immersion of the apparatus.

A second means of contamination is through the air. Carbonaceous dust metal chips of small diameter, small droplets of paint from nearby spray booths, and other foreign material may enter the varnish when the tank lid is open. Each varnish-treating room is equipped with overhead cranes and lifts which are additional possible sources of contamination. Also material foreign to the varnish may be added by mistake. The addition of a varnish whose resin is only slightly soluble in the varnish and solvent in the tank is an example. Here the foreign resin would be precipitated out, possibly as troublesome colloidal particles.

Contaminants generally may be classified as conducting and nonconducting. Carbonaceous dust, lint, metal particles, and electrolytes are offenders as conducting contaminants. These often are introduced by apparatus being processed, but can be present due to the manufacturing atmosphere. Nonconducting particles are represented by wood chips and precipitated or polymerized resins, pieces of cotton, and asbestos and mica dust. This type of material comes from pieces of insulation washed off the coils and wound apparatus on immersion in the varnish bath.

Contamination may be classified into three types by use of wet and dry dielectric tests and heat-endurance tests Conducting particles lower wet and dry dielectric strength and generally impair the heat endurance of the varnish film. A second type is identified by a high dry dielectric strength, a low wet dielectric strength, and a low heat endurance. Contamination producing varnish gels or precipitated resins might not lower the dielectric strength but would lower the heat endurance or life of the varnish film.

Disruption of the varnish film by particles of foreign matter seriously impairs the properties of the insulation. On electrical equipment there is no need to mention the effect of conducting or ionizing particles on the dielectric breakdown value, particularly when they become imbedded in the insulation. In some cases, although the particles are not conducting, they cut into the insulation during processing, lowering the breakdown level of the material. In addition, the initial mechanical strength and life or endurance of the varnish film are reduced when foreign materials contaminate the varnish.

Thus, it is important to keep varnish for treating electrical equipment as clean from foreign material as possible. As a base or goal, the electrical properties and mechanical properties should be kept in the same order of magnitude as those of the new varnish.

Varnish Tests

To control the varnish adequate tests must be worked out which reflect the condition of the tank. Some of these are of a type which permit testing at the tank itself, whereas others require sampling of the varnish and testing in a chemical laboratory.

Those test methods which are practical to apply at the tank must be simple and require only a short time to perform. Viscosity and specific-gravity measurements fit easily into a daily inspection routine. Viscosity measurements may be made by one of several methods. The simplest of these involves the use of a cup with a calibrated orifice in the bottom which allows varnish to flow in or out at a definite rate. The time a definite volume of varnish fills or empties from this cup may be taken as a measurement of viscosity. Another method is to fill a convenient-length transparent tube with varnish. A small bubble is left at the top. When turned end for end the bubble rises slowly. The time required by the bubble to travel a certain distance is a measure of viscosity. However, a number of tubes with liquids of known viscosity may be used. The rate of rise of the bubble in the tube of tank varnish will be approximately the same as for one of the bubbles in a tank containing a liquid of known viscosity. The viscosity of the tank varnish is taken as the same as the liquid whose bubble rises at the same rate.

Viscosities with the cup or tube methods may be reported directly in seconds and will be comparable to other determinations made with the same apparatus. This is the most convenient arrangement.

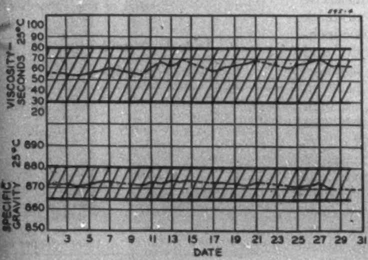


Figure 4. Daily varnish checks in tank of oleo resinous varnish, April 1 through April 30, 1944

Shaded area shows limit specified

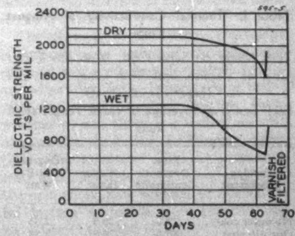


Figure 5. Wet and dry dielectric strength of heat-reactive varnish

Figure 6. View of the portable pressure filter showing the perforated stainless-steel filter plates

However, conversion to classical viscosity units may be made easily.

Specific gravity is taken easily with a hydrometer. Precautions should be taken to prevent bubbles in the varnish sample from contributing to erroneous results. Care should be exercised that the spindle be read at the surface of the liquid, not at the "high-tide" mark of the varnish.

Both specific gravity and viscosity are dependent upon temperature. Corrections to a standard base temperature are simple and should be made in all cases to provide a common basis of discussion. A value of 25 degrees centigrade is recommended as the standard base (refer to Figure 3 for a typical correction curve). The combination of viscosity and specific gravity, however, give many useful indications. Although samples for body may be taken at frequent intervals, this test requires an oven and despite its simplicity must be classified as a laboratory test.

Samples for laboratory tests should be taken at convenient and regular intervals. A number of tests have proved significant. Body of course is determined easily by evaporating the solvent and weighing the remaining resin. Body determination should be made more frequently than other laboratory tests since the information obtained is useful for correlation with the daily viscosity–specific-gravity determinations.

Other properties of varnish are not evaluated so easily. Wet and dry dielectric strengths of varnish films on copper panels, hardness of varnish cakes, heat endurance, oil resistance, and drying time all are important.[2] Many of these tests are affected by dust-laden atmospheres, by humidity conditions, and by temperature. They should be performed in a dust-free and moisture- and temperature-controlled room.

Dielectric strengths and heat endurance of varnish films have become important measures of the degree of varnish contamination. Heat endurance is determined by depositing varnish films 0.002 inch thick on copper strips 0.005 inch thick.[3] These are heated continuously at 150 degrees centigrade for accelerated tests, as suggested by Frost and Moses.[3] The time to produce failure of the film on bending about a one-eighth-inch mandrel is reported as the heat endurance of "flexing life." Dielectric tests consist of measuring the dielectric breakdown strength of a 0.002-mil-thick varnish film on each side of a 0.005-inch-thick copper sheet as received dry and after immersion in water for 24 hours.

Hardness measurements are made on varnish cakes at least one eighth inch thick with a Shore durometer *A*.[5] The measurements are taken after three hours bake at 135 degrees centigrade and again after six hours at 135 degrees centigrade. A further durometer measurement after 48 hours in oil at 110 degrees centigrade allows evaluation of the oil resistance of the varnish. These measurements are dependent upon temperature, and tests should be in a controlled atmosphere if possible. Drying time determinations should be made as per American Society for Testing Materials specifications (*D*115–39*T*).[2] A one-mil varnish film is deposited on a copper plate and baked at 110 degrees for baking varnishes. At intervals a strip of kraft paper is pressed upon the surface. The drying time is taken as that time when the paper does not stick to the panel.

From these data a representative picture of the condition of the tank varnish can be drawn. Contamination and chemical changes can be noted quickly and steps taken to compensate for these changes where necessary. Table II consists of a typical report on laboratory varnish tests.

Table I. Thermal Conductivity of Magnet Coils

Tests Made on Same Coil, With No Outer Coat of Varnish, and With One, Two, and Three Varnish Coats

Each Test Is an Average of Three Temperature Runs

Varnish Treatment	Rise, Degrees Centigrade	Watts Input	Degrees Rise Per Watt
No outer coat	77.5	29.2	2.65
One dip coat	82.5	29.2	2.83
Two dip coats	85.5	29.3	2.92
Three dip coats	86.0	28.4	3.02

Inspection System

An inspection system is essential to insure proper quality control of tank varnish. Inspectors should be assigned the responsibility of checking and adjusting varnish tanks and inspecting new varnish to be added to tanks. Each active tank should be checked for viscosity and specific gravity daily. It is not enough merely to inspect; tanks must be adjusted daily within definite limits by addition of solvent or new varnish. If tanks are not within the proper limits of viscosity and specific gravity, they should not be used until proper adjustments are made.

Limits of viscosity and specific gravity are set for each type of treatment and each type of varnish in the tank. Daily examinations should be made of the varnish for dirt, varnish skins, or gels. All varnish should come within specifications in all characteristics before addition to tanks. A single drum of overpolymerized varnish can initiate rapid polymerization throughout a large tank which may lead to scrapping. Daily records or curves may be kept of each tank with additions of solvent and new varnish indicated. At the end of each month a report on the condition of the varnish tanks should be made to interested parties. By the use of curves viscosity and specific-gravity trends can be followed and the necessity for adjustments readily seen.

Figure 4 is a record of the inspector's

Table II. Varnish Tests

Sample 58

Body	53.56 per cent
Specific gravity	0.985
Viscosity (Demmler 1) (25 C)	132 seconds
Drying time (ASTM at 110 C)	2 hours
Hardness varnish cake at 25 C (durometer *A*):	
3 hours bake at 135 C	2
6 hours bake at 135 C	24
48 hours in oil at 110 C	29
Flexing life (150 C)	60 hours
Wet dielectric	900 volts per mil
Dry dielectric	1,800 volts per mil

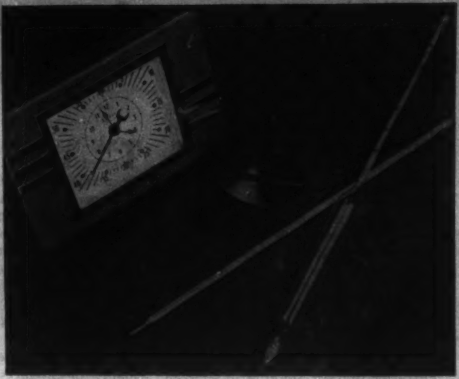


Figure 8. Varnish inspector's test material

These include: stop watch, viscosity measurement cup, thermometer, hydrometer

monthly report on specific gravity and viscosity of a tank of synthetic varnish. Note limits of viscosity and specific gravity for that particular tank.

In addition periodic chemical laboratory examinations should be made of every varnish tank to follow changes in electrical and mechanical properties. All of this is insurance against improper treatment of equipment. The benefits are apparent in the improved appearance of coils and wound apparatus and improved performance. Actual economies are hard to estimate.

Varnish and solvent added must be carefully mixed into the tank. Improperly mixed solvent will rise to the top in a separate phase, whereas the more viscous and dense varnish will tend to form a layer at the bottom of the tank. Either phenomenon results in stratified layers each with its own viscosity and body. Such a tank will not deposit consistently good protective films. This condition may be remedied by simple but thorough mixing of each drum into the tank as it is added.

Filtration

Careful control of the varnish requires an adequate filtration method.[1,6] The materials used in varnish manufacture are critical, and maintenance of the varnish in usable condition is essential. The particle sizes of contaminants range from large pieces of wood to colloidal carbon. Pieces of metal as small as 0.003 inch in diameter have been found. A study of the available methods suggested that the most efficient method of reclamation of the varnish and conservation of critical materials is by cold pressure filtration.

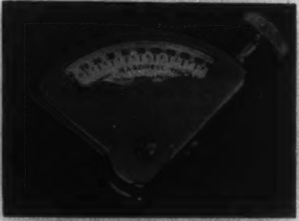
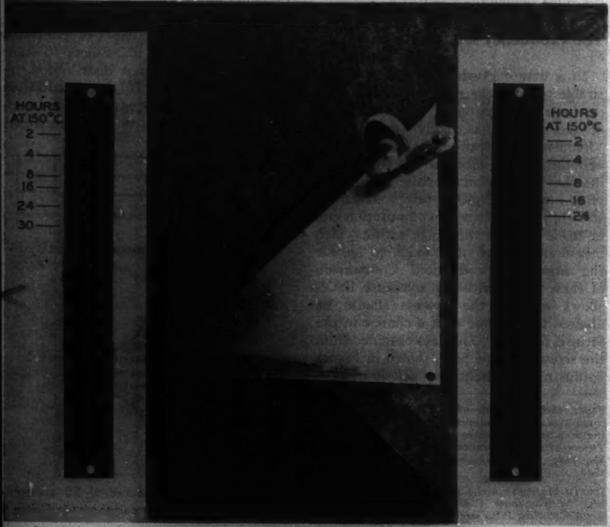


Figure 9. A Shore durometer for testing hardness of the varnish

Figure 7(below). Dielectric and heat-endurance panel

The dielectric panel has been slit to facilitate measuring thickness of the varnish film. Cracks in varnish film on heat-endurance strips indicate failure of the varnish



A portable-type pressure filter, consisting of a number of plates arranged vertically and enclosed in a shell, has been found to be satisfactory. Pressures of 15 to 28 pounds per square inch are used, with rates of flow varying from one to five gallons per minute depending upon the pressure, amount of cake, and viscosity of filtrate.

Filtration is carried out using a diatomaceous earth as a filter aid. This is particularly necessary as some of the contaminating material filtered out is a gel and quickly fills up the pores of the filter medium. The addition of filter aid allows a porous cake to build up which is not so easily clogged as the filter medium alone. In order to avoid addition of the filter aid to the large varnish tanks small portable tanks may be set up in which the diatomaceous earth may be mixed continuously with the incoming varnish stream. Varnish is pumped from here through the filters and into a clean tank in the system.

The efficiency of the filtering treatment is judged by a series of chemical and physical tests on samples taken before and after filtration. Percentage of body, viscosity, and specific gravity show whether or not there is a loss of solvent or varnish resin during the filtering operation. The results of the heat-endurance tests and dielectric tests before and after the operation show whether or not harmful foreign materials were present and have been removed.

Improvements in dielectric properties produced by filtering the varnish are remarkable. A typical increase in dry dielectric strength in the order of 30 per cent and in the wet dielectric strength in the order of 70 per cent was found (see Figure 5). Heat endurance and the mechanical properties of the varnish improved from 10 to 20 per cent upon filtering. In one case a badly contaminated sample was filtered with a resulting improvement in heat endurance of over 100 per cent. Plastic asphalt-type varnish improved in this characteristic over 40 per cent after filtering. An increase in heat endurance indicates that particles of colloidal matter which damage the varnish film have been removed. It is apparent that the type of contaminant depends upon the material treated in the tank. The length of time between filtering operations depends upon the use or activity of the tank.

Filtration in itself would be of no avail if the filtered varnish is pumped back to become recontaminated by dirty tanks. Tanks should be cleaned periodically; frequent filtrations provide an opportune time for cleaning.

Conclusions

Thus a system of varnish control which includes testing and inspection of varnish and methods of maintenance is essential in sustaining the quality of insulating varnishes. Such a system will reduce the number of possible sources of electrical failures in shop testing and in the field. In addition it will eliminate certain manufacturing problems. The economies resulting from longer use of the varnish are difficult to estimate. This control and filtration system is a step forward in the conservation of critical varnish materials. It should be recognized by the electrical industry that insulating varnishes are complex chemical mixtures, and care should be exercised in their use. Persons of the proper training and experience are required for their supervision. Constant quality control is necessary for satisfactory use of insulating varnishes.

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Statistical Tools for Controlling Quality

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THE MANUFACTURER is always faced with the problem of getting the maximum output from his available equipment, material, and man power. This means operating with a minimum amount of scrap production or producing a minimum amount of products which fall outside of specification limits and which will require reworking. But since tools of production are subject to wear, and since materials vary in quality or characteristics, the manufacturer must have a means of predicting the probable quality of products he is likely to get sometime in the future.

Having satisfied himself that his quality is satisfactory now, he wants to be able to control or maintain that quality indefinitely, or as long as that particular product is made. This prediction must be clear and definite enough to serve as the basis for action to remove assignable causes which if not removed will result in the production of parts outside of specification limits.

Furthermore, in modern mass production where several tools perform the same operation, as with multicavity molds and gang cutters, the manufacturer wishes to know if there is any significant difference in the quality of products coming from different cavities in the same mold or from different cutters in the same setup involving a number of cutters on the same machine.

The Frequency Distribution

In a manufacturing process, it is desirable to know, as soon as possible after production is started, what the quality of the product is likely to be. The "frequency distribution" is a simple way of obtaining this information. By measuring the quality characteristic in question on a number of pieces produced at the start of a run, a simple computation can be made to show the range within which measurements are most likely to fall for the subsequent production. Comparison of these limits with the tolerance limits shows whether the process should be allowed to continue or if a change in the setup is required. The data obtained from the screw-machine part, shown in Figure 1, illustrate the frequency distribution.

A sample of 50 pieces was taken and each piece was measured for over-all length, which was required to be 4.450 inches ± 0.010 inch. The measurements obtained are shown in Table I.

The data in Table I do not give much information in their present form. However, the data can be reorganized as shown in Table II so as to become very enlightening. A survey of the data shows that exactly 16 pieces were 4.450 inches long, eight pieces were 4.451 inches long, nine pieces were 4.449 inches long, and so on.

Such a table is called a *frequency distribution.* It indicates the number, or frequency of occurrence, of measurements in each size. In practice, the pieces may be tallied as they are measured, as is shown in Figure 2. This gives visual meaning to the frequency distribution. It will be noted that the distribution is bell-shaped and symmetrical about the center, high in the center, and falls off sharply at both ends. The envelope curve of the tallied marks is known as the *frequency curve.* For best-quality production the frequency curve must lie totally within the specification limits.

Figure 3 shows the frequency curve, for this part, in relation to the specification limits. It is evident, in this case, that the process is capable of producing good pieces and will continue to do so provided nothing happens to change the shape or location of the frequency distribution. A periodic check of five pieces per hour on this item, suffices to show whether the frequency distribution remains unchanged. If the distribution does remain unchanged the entire production is considered to be within toler-

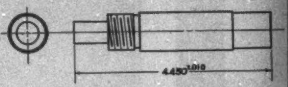

Figure 1. Screw-machine part

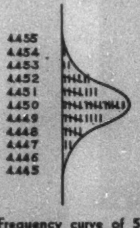

Figure 2. Frequency curve of 50 measurements on screw-machine part shown in Figure 1

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Table I. Fifty Measurements on Screw-Machine Part Shown in Figure 1 (Inches)

1. 4.450	14. 4.451	27. 4.450	40. 4.450
2. 4.449	15. 4.448	28. 4.450	41. 4.449
3. 4.449	16. 4.450	29. 4.448	42. 4.447
4. 4.450	17. 4.451	30. 4.450	43. 4.448
5. 4.452	18. 4.451	31. 4.450	44. 4.449
6. 4.452	19. 4.452	32. 4.450	45. 4.449
7. 4.451	20. 4.454	33. 4.448	46. 4.450
8. 4.452	21. 4.453	34. 4.449	47. 4.451
9. 4.451	22. 4.450	35 4.450	48. 4.450
10. 4.451	23. 4.450	36. 4.450	49. 4.448
11. 4.452	24 4.453	37. 4.452	50. 4.449
12. 4.452	25 4.449	38. 4.450	
13. 4.451	26. 4.447	39. 4.449	

Table II. Frequency Distribution of 50 Measurements on Screw-Machine Part Shown in Figure 1

Length of Piece (Inches)	No. of Pieces
4.455	0
4.454	1
4.453	2
4.452	7
4.451	8
4.450	16
4.449	9
4.448	5
4.447	2
4.446	0
4.445	0

ance limits, and final inspection may be dispensed with. The central location of the frequency distribution with respect to the specification limits and its narrowness compared to the tolerance range guarantee that the product is of high quality.

The shape and position of a frequency curve with respect to the specification limits are indicative of assignable causes which must be corrected if products being produced are to be kept within specification limits. Two types of curves most frequently encountered are shown in Figure 4A and Figure 4B.

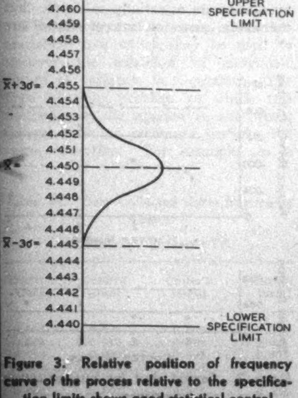

Figure 3. Relative position of frequency curve of the process relative to the specification limits shows good statistical control

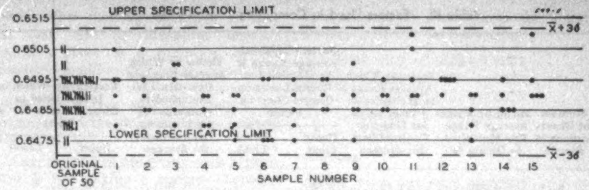

Figure 5. Typical control chart for samples of five pieces, showing individual observations

Figure 4A is an example of a process for which the band spread, or the variation from part to part, is narrow enough to produce a good product, but the machine is not properly adjusted. In other words, the frequency distribution is not centralized with respect to tolerance limits. As a matter of fact, this distribution was obtained, at an earlier stage of the process when the machine was being set up to produce the part, the distribution of which is shown in Figure 3.

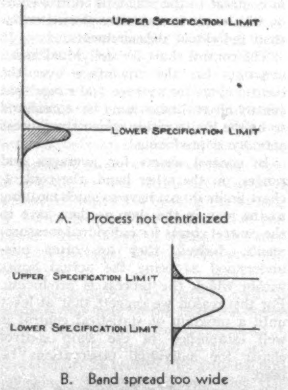
UPPER SPECIFICATION LIMIT
LOWER SPECIFICATION LIMIT
A. Process not centralized
UPPER SPECIFICATION LIMIT
LOWER SPECIFICATION LIMIT
B. Band spread too wide

Figure 4. Typical frequency curves showing assignable causes

Figure 4B illustrates a frequency distribution which has a wider band spread than the tolerance range. Such a situation may be easily remedied. A few assignable causes indicated by a wide band spread are worn bearings in the machine, flimsy and unstable fixtures, and excessive variation in hardness of stock.

It should be apparent from the foregoing discussion that a frequency distribution has two characteristics which are of practical importance, the "central tendency" and the "amount of band spread" or degree of dispersion. These characteristics may be represented numerically by the mean, $\bar{X}$, and standard deviation, σ. The standard deviation is merely the root-mean-square value of the deviations. Another characteristic of a frequency distribution is its skewness, or amount of deviation from symmetry, but we are not particularly interested in this at present. A normal process will have a distribution which is nearly symmetrical. Statistical tests exist for symmetry, but one is often able to judge by sight whether or not a given frequency distribution is sufficiently symmetrical for purposes of controlling quality.

The Control Chart

After control of quality has been achieved by means of the frequency distribution, and production is under way, it is necessary to maintain this control in order to avoid the production of defective parts. The control chart is the tool used for maintaining this control; it is a take-off from the frequency distribution. It is necessary to calculate the mean, $\bar{X}$, and standard deviation, σ, from the frequency distribution in order to establish limits for the control chart. In many cases a rough approximation of the control limits may be obtained from an inspection of the frequency distribution.

After it has been established that $\bar{X}$ and σ are satisfactory for the process, and a control chart has been constructed, a periodic check of, say, five pieces is sufficient to detect tendencies toward loss of control. The time interval between samples may be an hour or a day, or a sample might represent a batch of material. The choice of samples is governed by such factors as tool wear, skill of operator, closeness of specification limits, and rate of production. Practically all measurements made on samples should fall within a distance of 3σ from $\bar{X}$, or within the "control limits." If any measurements fall more than 3σ from $\bar{X}$, this is a strong indication that a change has occurred in the process at those points which has changed the frequency distribution.

As an illustration, consider the data of Figure 5, which were obtained from a dimension on the breech block of an antiaircraft gun. The dimension is 0.6495 inch ± 0.002 inch. As shown in the figure, a frequency distribution of 50 measurements was obtained and $\bar{X}$ and σ computed. The results of this computation are $\bar{X}=0.6491$ inch and $\sigma=0.0007$

Table III. Factors Used in Computing Control-Chart Limits

Number of Observations in Sample	Factor by Which Average Range $\bar{R}$ Is Multiplied to Obtain 3σ	Factor by Which Average Range $\bar{R}$ Is Multiplied to Obtain $3\sigma/\sqrt{n}$ for Limits on Control Chart for Average	Factors by Which Average Range $\bar{R}$ Is Multiplied to Obtain Limits on Control Chart for Range		Factor by Which Average Standard Deviation σ Is Multiplied to Obtain $3\sigma/\sqrt{n}$ for Limits on Control Chart for Average	Factors by Which σ Is Multiplied to Obtain Limits for σ Chart	
			Upper Limit	Lower Limit		Upper	Lower
3	1.77	1.02	2.57	0	2.39	2.69	0
4	1.46	0.73	2.28	0	1.88	2.33	0
5	1.29	0.58	2.11	0	1.60	2.13	0
6	1.18	0.48	2.00	0	1.41	2.00	0
7	1.11	0.42	1.92	0.08	1.28	1.90	0.10
8	1.06	0.37	1.86	0.14	1.18	1.83	0.17
9	1.01	0.34	1.82	0.18	1.09	1.77	0.23
10	0.97	0.31	1.78	0.22	1.03	1.72	0.27

Table IV. Turbine-Blade-Edge Thickness Above Nominal (Inch)

	Cutter 1	Cutter 2	Cutter 3	Cutter 4
Cam 1	0.004	0.004	0.009	0.016
Cam 2	0.008	0.010	0.015	0.022
Cam 3	0.007	0.008	0.010	0.015
Cam 4	0.009	0.009	0.012	0.018
Cam 5	0.009	0.011	0.022	0.027
Cam 6	0.004	0.007	0.013	0.017

inch. Thus $\bar{X}-3\sigma=0.6470$ inch, and $\bar{X}+3\sigma=0.6512$ inch. Dotted lines are drawn at $\bar{X}-3\sigma$ and $\bar{X}+3\sigma$. These are called "control-chart limits." In this example 15 samples each containing five measurements were then obtained—a sample a day for 15 consecutive days. As is apparent from the chart, all 75 measurements fall within the control-chart limits. The process accordingly is considered to be "in control."

In this particular example, the control-chart limit falls below the lower specification limit by 0.0005 inch. Hence, although the process is consistent—therefore, in control—it is not quite centralized and has a slightly too wide band spread. Accordingly, the process will produce some defective pieces, and adjustments should be made to assure that all pieces are within specification limits. This emphasizes the fact that there are three statistical requisites of a process—control, centralization, and small band spread.

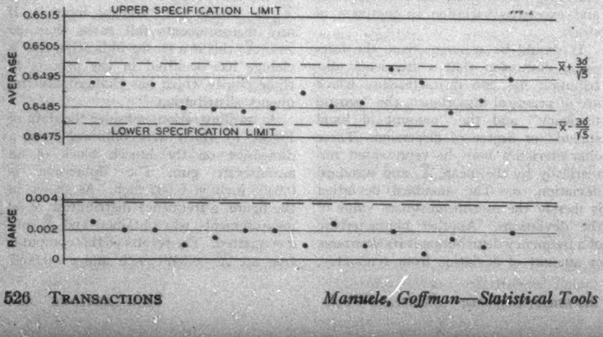

Figure 6. Control chart for "average" and "range"

It should be noted that every measurement of the five pieces in each sample actually is plotted on the chart. This is in contrast to the standard control chart on which only averages are plotted rather than individual measurements.

The control chart for individual measurements has the advantage over the control chart for average and range that control-chart limits may be considered to be the limits within which the process actually is producing.

In control charts for averages and ranges, on the other hand, the control-chart limits do not have so much meaning to the man in the shop as they have in the control charts for individual measurements. Indeed, they are often misunderstood as being the actual limits within which the process is producing. For this reason we suggest that at least until a program of statistical control is well established in the shop control charts for individual observations be used.

In a control chart for averages, charts are run simultaneously for "average" and for "range" or "standard deviation." "Range" is simpler to calculate than "standard deviation" and will be used here. In Figure 6 we have such a control chart for the data of Figure 5. The average was computed for each of the 15 groups of five measurements, and the results are plotted on the "average" chart. The ranges are plotted on the "range" chart.

Table V. Showing Calculation of Between-Column Variance and the Ratio of Between-Column Variance to Within-Column Variance (Inch)

	Cutter 1	Cutter 2	Cutter 3	Cutter 4
Cam 1	0.004	0.004	0.009	0.016
Cam 2	0.008	0.010	0.015	0.022
Cam 3	0.007	0.008	0.010	0.015
Cam 4	0.009	0.009	0.012	0.018
Cam 5	0.009	0.011	0.022	0.027
Cam 6	0.004	0.007	0.013	0.017
Totals	0.041	0.049	0.081	0.115
$\bar{X}_{cu}$	0.0068	0.0082	0.0135	0.0192

$$\bar{\bar{X}}_{cu}=\frac{\sum_{1}^{4}\bar{X}_{cu}}{4}=0.0119$$

The between-column variance is

$$\frac{6\Sigma(\bar{X}_{cu}-\bar{\bar{X}}_{cu})^2}{(4-1)}=0.0001911 \text{ inch}$$

The within-column variance is 0.00001350 inch.

$$\frac{\text{Between-column variance}}{\text{Within-column variance}}=\frac{0.0001911}{0.0000135}=14.1$$

Obviously, averages of five measurements obtained from a process will not deviate from each other by as much as will the individual measurements themselves. The control-chart limits for averages accordingly must be drawn much closer together than for individual measurements. For averages of five, the factor of shrinkage is $\sqrt{5}$. The control-chart limits for averages are therefore $\bar{X}-(3\sigma/\sqrt{5})$ and $\bar{X}+(3\sigma/\sqrt{5})$. If the values $\bar{X}=0.6489$ inch and $3\sigma=0.0023$ inch are substituted, the control-chart limits become 0.6479 inch and 0.6499 inch. Factors for computing these limits and limits for the range chart are given in Table III.

It should be stated that the control chart frequently is used in such a way as actually to tell the source of trouble as well as the existence of trouble. The reason for this is that most machine-shop operations are essentially so simple that the likely causes of lack of control are

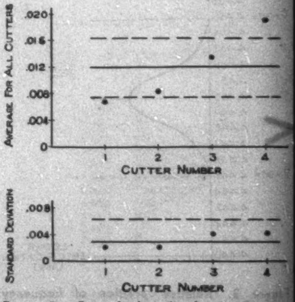

Figure 7. Control chart for between-cutters variance

few in number and are known beforehand, and it is easy to discern which will manifest itself as a lack of control of ranges and which as a lack of control of averages.

For example, we mention briefly a grinding operation on bars of rectangular stock which were running off as much as 0.004 inch. This was considerably excessive. The operation was performed by placing about 50 bars on a magnetic chuck and grinding with a circular motion. Two most likely causes of variation were dirt on the chuck and a variation in the distance to which the grinder was run down each time. A control chart for average and range was kept on the operation by taking groups of five bars at random from the 50 ground at each grinding. The first cause of variation obviously would show "range" out of control on the chart, and the second cause would show "average" out of control. The control chart showed both average and range out of control. By proper cleaning of the chuck, range was brought into control. Average was brought within control when steps were taken to assure that the grinder ran down to the same position each time. With a control chart on the operation to show that the right practice is being continued, the dimension is now held to 0.001 inch.

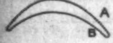

Figure 8. Sectional view of turbine blade

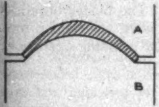

Figure 9. Showing method of gauging edge thickness of turbine blade

The Analysis of Variance

The analysis of variance is another statistical tool which may be used to uncover the existence of assignable causes of variation in a product. The type of shop problem to which this method may be applied is one where several tools or machines perform the same operation. For example, in a multicavity molding operation it may be that, due to differences between cavities, there is a variation in the product significantly greater than that which would exist if all the cavities were alike. It is true that tools which are supposedly alike do not always perform similarly.

Table VI. Data Collected After Regrinding Cutters

Compare With Table IV

Cutter 1 (Inch)	Cutter 2 (Inch)	Cutter 3 (Inch)	Cutter 4 (Inch)
0.002	0.003	0.002	0.003
0.003	0.010	0.004	0.004
0.008	0.006	0.002	0.004
0.003	0.006	0.003	0.003
0.008	0.010	0.010	0.018
0.003	0.007	0.001	0.006

One method of analyzing such a problem is by making a control chart, as shown in Figure 7. The standard deviation is computed for each tool, or cavity, and for the whole process. The control chart shows the average for the process and for each tool. Another statistical method which lends itself to this type of problem is the analysis of variance. We shall now illustrate this method, giving the calculation in detail.

An example of this type of problem is a drum-mill operation on turbine blades. The drum mill consists of a circular drum with six rows of pockets equally spaced around the circumference. Each row contains four pockets, making a total of 24 pockets, each holding a blade; there are six cams, one for each row, and four cutters, each of which cuts six blades, one from each row, as the drum rotates. Variations in the product can be caused by differences between cutters, between cams, or between the pockets themselves.

Figure 8 shows a cross-sectional view of the blade. The drum-mill operation considered consists of forming the surface *A*. This is called the "convex" of the blade. The surface *B*, called the "concave" of the blade, is formed on a previous operation.

Figure 9 shows the method used to measure the form of the blade. A feeler gauge inserted between the sections *A* and *B* of the gauge showed how much stock had to be removed by grinding and polishing. Statistical evidence that this could be controlled showed that the grinding operation was unnecessary. As a result of action taken on the basis of statistical data on this operation, this grinding operation was ultimately eliminated.

The data shown in Table IV were obtained for a single revolution of the drum. To learn whether a significant difference exists between cutters, the data are arranged as shown in Table V. The variance between columns and the variance within columns are then computed.

To Obtain Variance Between Columns

1. Obtain the average of each column. In this example the averages are $\bar{X}_1=0.0068$, $\bar{X}_2=0.0082$, $\bar{X}_3=0.0135$, and $\bar{X}_4=0.0192$, respectively, for the four cutters.

2. Obtain the grand average $\bar{\bar{X}}$ of all the measurements. In this example, $\bar{\bar{X}}=0.0119$.

3. Subtract the respective column averages obtained in item 1 from the grand average in item 2. In this example,

$$\bar{\bar{X}}-\bar{X}_1=0.0119-0.0068=0.0051$$
$$\bar{\bar{X}}-\bar{X}_2=0.0119-0.0082=0.0037$$
$$\bar{\bar{X}}-\bar{X}_3=0.0119-0.0135=0.0016$$
$$\bar{\bar{X}}-\bar{X}_4=0.0119-0.0192=0.0073$$

4. Square the results of item 3. In this example,

$$(\bar{\bar{X}}-\bar{X}\ )^2=(0.0051)^2=0.00002601$$
$$(\bar{\bar{X}}-\bar{X}_2)^2=(0.0037)^2=0.00001369$$
$$(\bar{\bar{X}}-\bar{X}_3)^2=(0.0016)^2=0.00000256$$
$$(\bar{\bar{X}}-\bar{X}_4)^2=(0.0073)^2=\underline{0.00005329}$$
$$0.00009555$$

5. Add the results of item 4. In this example, the total is 0.00009555.

6. Multiply the result of item 5 by the number of measurements in each column. In this example, there are six measurements in each column.
Therefore, we have $6\times0.00009555=0.00057330$.

7. Divide the result of item 6 by the total number of columns minus 1 (the degrees of freedom $=4-1=3$). In this example, there are four columns. Hence, we divide the result of item 6 by 3 to obtain $0.00057330\div3=0.00019110$. This last figure is the between columns variance.

To Obtain Variance Within Columns

1. Subtract each measurement from the average of the column in which it appears. In this example, the results are:

$0.0068-0.004=0.0028$
$0.0068-0.008=0.0012$
$0.0068-0.007=0.0002$
$0.0068-0.009=0.0022$
$0.0068-0.009=0.0022$
$0.0068-0.004=0.0028$

$0.0082-0.004=0.0042$
$0.0082-0.010=0.0018$
$0.0082-0.008=0.0002$
$0.0082-0.009=0.0008$
$0.0082-0.011=0.0028$
$0.0082-0.007=0.0012$

$0.0135-0.009=0.0045$
$0.0135-0.015=0.0015$
$0.0135-0.010=0.0035$
$0.0135-0.012=0.0015$
$0.0135-0.022=0.0085$
$0.0135-0.013=0.0005$

$0.0192-0.016=0.0032$
$0.0192-0.022=0.0028$
$0.0192-0.015=0.0042$
$0.0192-0.018=0.0012$
$0.0192-0.027=0.0078$
$0.0192-0.017=0.0022$

2. Square the results in item 1. In this example, the results are:

$$(0.0028)^2=0.00000785$$
$$(0.0012)^2=0.00000144$$
$$(0.0002)^2=0.00000004$$
$$(0.0022)^2=0.00000484$$
$$(0.0022)^2=0.00000484$$
$$(0.0028)^2=\underline{0.00000784}$$
$$0.00002685$$

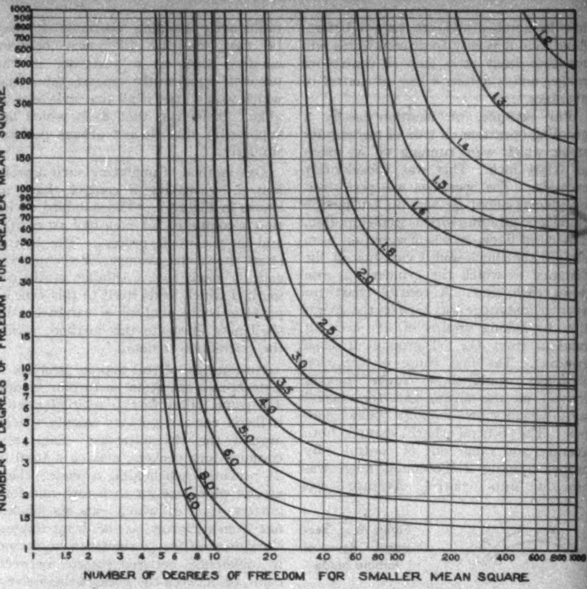

Figure 10. Analysis of variance chart—one-per-cent probability levels

$(0.0042)^2=0.00001764$
$(0.0018)^2=0.00000324$
$(0.0002)^2=0.00000004$
$(0.0008)^2=0.00000064$
$(0.0028)^2=0.00000784$
$(0.0012)^2=0.00000144$

0.00003084

$(0.0045)^2=0.00002025$
$(0.0015)^2=0.00000225$
$(0.0035)^2=0.00001225$
$(0.0015)^2=0.00000225$
$(0.0085)^2=0.00007225$
$(0.0005)^2=0.00000025$

0.00010950

$(0.0032)^2=0.00001024$
$(0.0028)^2=0.00000784$
$(0.0042)^2=0.00001764$
$(0.0012)^2=0.00000144$
$(0.0078)^2=0.00006084$
$(0.0022)^2=0.00000484$

0.00010284

3. Adding the column totals in item 2, we get a grand total of 0.00027003.

4. Divide the result of item 3 by the total number of measurements minus the total number of columns. In this example, there are 24 measurements and four columns. Hence, we divide 0.00027003 by 20. The answer, 0.00001350, is the within-column variance.

USE OF FIGURE 10 TO DETERMINE WHETHER DIFFERENCE IS SIGNIFICANT

1. Divide the between-column variance by the within-column variance. In this example, the result is $0.00019110 \div 0.00001350 = 14.16$.

2. The between-column degrees of freedom is the number of columns minus one. The within-column degrees of freedom is the total number of measurements minus the number of columns. In this example, the between-column degrees of freedom is 3 and the within-column degrees of freedom is 20.

3. Using the between-column degrees of freedom as ordinate and the within-column degrees of freedom as abscissa, locate the curve on Figure 10, passing through their intersection. In this case the point of intersection is almost at 5, and we shall call it 5.

4. If the answer obtained in item 1 exceeds the value on this curve, then a significant difference exists. In this example, the cutters produce significantly different parts, since 14.16 is greater than 5 $(14.16>5)$.

Hence it is necessary to regrind the cutters before running the operation. The cutters were reground and the data on Table VII were obtained. For these data, the between-column variance is 0.0000144 and the within-column variance is 0.0000129. Reference to Figure 10 shows that significant difference between cutters is unlikely. The blades obtained from these cutters were sufficiently uniform to eliminate the grinding operation.

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Basic Concepts of Moving-Magnet-Instrument Rotors

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DURING RECENT YEARS the progress made in the development of permanent-magnet materials has brought about a considerable increase in the use of permanent-magnet rotors in d-c instruments. One such application is in the d-c Selsyn position indicator,[1] another in a newly developed electric instrument,[2] and a third in a new ratio-type instrument.[3] The space limitations in these designs predicated small actuating elements which were obtained by using permanent-magnet moving systems.

In view of these developments and the increasing number of permanent-magnet materials now available, it is appropriate to analyze the basic concepts on which the design of permanent-magnet rotors should be based. Although it is not possible to cover all rotor shapes, the elliptic spheroid, which can be shown to have uniform internal magnetization, lends itself to complete analytical treatment. A general analysis of this shape made in terms of its major and minor axes can be used as a good approximation for many rotor shapes and gives a clear physical insight into the behavior of permanent-magnet rotors.

The demagnetization portion of the hysteresis loops for several permanent-magnet materials are shown in Figure 1A, with their more important properties listed in Table I. These data are based on tests made on ring samples or the equivalent and without the demagnetizing effects of air paths in the magnetic circuit. All practical permanent-magnet applications, however, involve such air paths, and the designer is faced with the problem of applying these ring-sample data to designs subject to the demagnetizing effects of air paths.

The objects of this paper are:

1. To provide the instrument designer with a method for determining from ring-sample data and appropriate demagnetizing factors the intrinsic induction and the magnetic moment of a given rotor design.

2. To show how the value of the minimum field strength necessary to magnetize the rotor fully follows logically from the analysis.

3. To present a graphical method for determining the effect of an externally impressed field on a magnetized rotor.

4. To outline a scientific approach to the selection of materials for such applications.

Demagnetizing Factor of a Ring and Air Gap

The conventional analysis of permanent magnets usually deals with the case of a simple ring and air gap as shown in Figure 2B. The concept of a demagnetizing factor is not introduced as such, although it actually occurs in the relation which is established between the intrinsic induction and the magnetizing force. It is worthwhile, therefore, to re-examine the conventional analysis to identify this factor which is essential to the analysis of the magnetized rotor of elliptic-spheroid shape.

In the conventional analysis,[5] Ampere's law, $\oint H \cdot dl = 0$, is applied to the case of the ring and air gap to obtain the expression:

$$H_m l_m + B_g d = 0 \tag{1}$$

where H_m is the magnetizing force in the material in oersteds, B_g is the flux density of the gap in gausses, l_m is the mean length of the magnetic material in centimeters, and d is the air-gap length in centimeters.

The assumption is then made that the leakage flux is negligible so that the flux density in the material,

$$B_m = B_g \tag{2}$$

Equation 1 then becomes

$$\frac{B_m}{H_m} = -\frac{l_m}{d} \tag{3}$$

But in the electromagnetic system of units, which is used throughout this paper

$$B_m = B_{im} + H_m \tag{4}$$

where B_{im} is the intrinsic induction in the material for a given value of H_m as determined experimentally by a ring-sample test. Thus

$$B_{im} = f(H_m) \tag{5}$$

where $f(H_m)$ is the demagnetizing portion of the major hysteresis loop for the continuous ring of the material as shown in Figure 2A.

Equations 3 and 4 then are combined to obtain

$$B_{im} = -\left(\frac{l_m + d}{d}\right) H_m = -\frac{1}{\left(\dfrac{d}{l_m + d}\right)} H_m \tag{6}$$

As indicated in Figure 2C, the equations 5 and 6 can be solved graphically for the values of B_{im} and H_m needed to provide an approximation of the air-gap flux density available from the permanent-magnet circuit shown in Figure 2B. It should be emphasized that the analysis is based on the assumption that the leakage flux is negligible and that the resulting value of flux density is in error to the extent that this assumption varies from actual conditions.

In the graphical solution of equations 5 and 6, the slope of the line OQ, which represents equation 6, is given by the coefficient of H_m. The value of $\frac{d}{l_m + d}$ may be defined as the *demagnetizing factor*, K, for this magnetic circuit as it determines the amount by which the intrinsic induction, B_{im}, is reduced from its residual value, OS, to its value, OR, in the magnetic circuit as a result of the demagnetizing effect of the air gap. An increase in the value of K reduces the value of OR.

Demagnetizing Factor of a Permanent-Magnet Rotor

The concept of the demagnetizing factor which has been identified for the relatively simple analysis of ring and air-gap magnets, greatly facilitates the more complex analysis of permanent-magnet rotors. It permits engineers to translate the results of the analysis of a difficult field problem into terms of magnetic-circuit theory which is more widely understood.

In the general case, a permanent-magnet rotor of any shape will not be uniformly magnetized when it is immersed in a uniform magnetic field. For example, the intrinsic induction in a rectangular bar magnet varies from a maximum at its center to a minimum close to its ends. Thus internally the intrinsic induction must be represented as a space function of some selected co-ordinate system. Under such conditions, the concept of a single demagnetizing factor is not valid. This factor becomes a demagnetizing function, to be specified from point to point within the rotor, and the mathematics required to evaluate it is lengthy, difficult, and beyond the scope of this paper.

If, however, a shape is chosen in which the intrinsic induction is uniform, a straightforward analysis using a single demagnetizing factor is possible. Such a shape is an elliptic spheroid, the surface of which is generated by rotating an ellipse about either its major or minor axis to develop the prolate or oblate forms of it

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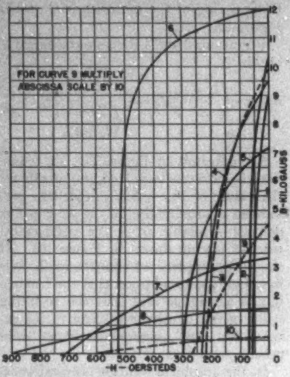
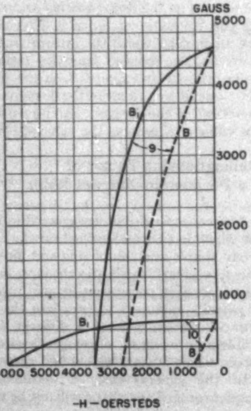


A. Curves for materials numbered 1 through 10 in Table I in terms of flux density, *B*, and demagnetizing force, *H*



B. Curves for cobalt–platinum– and silver–aluminum–manganese alloys in terms of *B* and *H* and also in terms of intrinsic induction, B_i, and demagnetizing force, *H*

Figure 1. Demagnetizing curves for permanent-magnet materials

shown in Figures 3A and 3B, respectively. Uniform intrinsic induction has been proved to occur in magnets of this shape if they are magnetized either along the generating axis or normal to it.[4] This shape has been used successfully as an approximation of many permanent-magnet-rotor designs. In doing so, the designer must distinguish clearly between the generating axis of the elliptic spheroid and the axis about which the rotor turns in the instrument. These axes may either coincide or be normal to one another. In addition, it should be noted that the direction of magnetization is always normal to the axis of rotation in the instrument.

The problem of determining the demagnetizing factor for the elliptic spheroid necessitates solving Laplace's equation $\Delta^2F=0$ for the magnetomotive force distribution of the rotor and the applied uniform field. In addition, the basic physical relations[5] must hold at the boundary surface. With the magnetomotive-force distribution determined, the flux paths are found and then the demagnetizing factor. Another method of approach[4] recognizes the solution of Laplace's equation required for uniform magnetization by analogy with the gravitational potential theory, and from this solution the demagnetizing factor for the elliptic spheroid is found. In any case the simple use of Ampere's law as outlined for the ring and air gap cannot be used until the flux paths are determined.

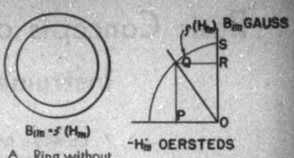
In Appendix I equations are given for the demagnetizing factors for the two forms of the elliptic spheroid, each magnetized either along the generating axis or normal to it. From these equations curves of the demagnetizing factors for values of the ratio of the generating axis to the axis normal to it are shown in Figure 4A. Figure 4B illustrates the elliptic-spheroid approximation of a short cylinder and also of a thin disk. The relationship among the three mutually orthogonal axes, the appropriate axis ratio *c/a*, and the demagnetizing factor *K* are indicated in each case.

DETERMINATION OF THE INTRINSIC INDUCTION AND MAGNETIZING FORCE

The demagnetizing factors given by the curves in Figure 4A can be used to determine the intrinsic induction and magnetizing force for elliptic-spheroid rotors of any dimensions. In Figure 3A such a rotor is introduced into a uniform field of magnetizing force H_A. The source of this magnetizing force is assumed sufficiently large so that the presence of the rotor in the field has negligible effect on it. The rotor causes a redistribution of this original field outside the rotor which may be attributed to a distribution of poles on the surface as shown. The pole distribution which is associated with the intrinsic induction exerts a demagnetizing effect on the original field H_A within the rotor, and the final magnetizing force H_x in the material, while still uniform, is reduced to a smaller value than H_A. The reduction in internal magnetizing force is proportional to the intrinsic induction. The constant necessary to determine this proportion is the demagnetizing factor *K*. Thus

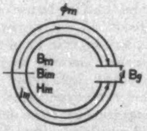
$$H_x=H_A-KB_{ix} \tag{7}$$

where H_x is the resultant magnetizing force in the material in oersteds, B_{ix} is the intrinsic induction in the direction *x* in gausses, and *K* is the demagnetizing factor which depends on the ratio of the length of axis *c* to that of axis *a*.



A. Ring without air gap for determining fundamental data of Figures 1 and 2

C. Graphical construction for determining operating point *Q* of ring and air-gap magnet



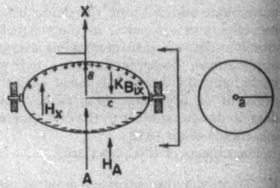
B. Ring and air-gap magnet

Figure 2. Conventional ring-shaped magnet

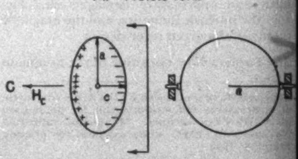
In equation 7 H_A is known, and *K* can be determined from Figure 4A. Two unknowns B_{ix} and H_x remain to be found. Hysteresis loops for the material based on ring-sample tests represented graphically or in symbols as $B_{ix}=f(H_x)$ furnish the other relationship needed to obtain numerical results. With equation 7 transposed, the problem may be formulated as follows:

$$\left.\begin{aligned}B_{ix}&=(1/K)(H_A-H_x)\\B_{ix}&=f(H_x)\end{aligned}\right\} \tag{8}$$

These equations can best be solved graphically to obtain numerical results. In Figure 5 *OM* is laid off equal to the magnetizing force H_A. The line *MP* is of



A. Prolate form



B. Oblate form

Figure 3. Elliptic spheroid

The intrinsic induction is always normal to the axis of rotation

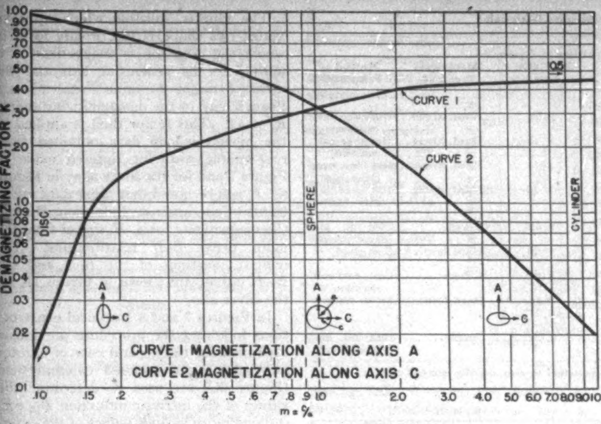
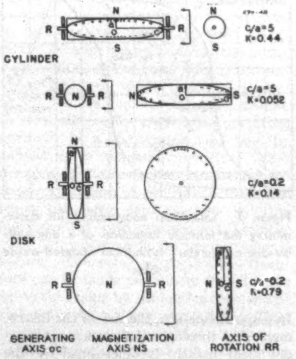


Figure 4

A (above). Curves giving values of the demagnetization for elliptic-spheroid rotors in terms of the axis ratio c/a

B (right). Elliptic-spheroid approximation of a short cylinder and of a thin disk



such slope that *PN* read on the ordinate scale divided by *NM* read on the abscissa scale equals $1/K$. As the major hysteresis loop is a multivalued function, there are three solutions *P*, *Q*, *R*, for this particular value of H_A, depending on how the magnetization takes place.

When the rotor is saturated by a large value of H_A which is then reduced to zero, its magnetic characteristics are represented by the point P_1, the ordinate and abscissa of which are the values of the intrinsic induction (B_{ix}) and the demagnetizing force ($-H_x$) for the permanent-magnet rotor. The point P_1 is found by the intersection of a line from the origin having slope $1/K$ and the demagnetizing portion of the hysteresis loop.

The magnetizing force H_A' needed to saturate the rotor can be obtained from the value H_s of this force required to saturate the ring sample. H_A' is determined by the intersection of a line drawn from *S* having slope $1/K$ and the abscissa. H_A' is larger than H_s because of the self-demagnetizing effect of the rotor shape. Thus the value needed to saturate a thin disk magnetized across its thickness is usually many times that required for the ring sample, and that for a long axially magnetized cylinder is nearly equal to it.

The foregoing analyses have been based on ring-sample hysteresis loops in terms of the intrinsic induction (B_{ix}) and the magnetizing force (H_x) rather than the more usual terms of flux density (B_x) and magnetizing force (H_x). When only the latter are available, B_{ix}–H_x curves are readily obtainable as $B_{ix}=B_x-H_x$. The B_{ix}–H_x relation is preferred for permanent-magnet-rotor analyses, as the intrinsic induction is equal to the magnetic moment per unit volume from which the mechanical torque provided by the rotor for instrument indication can be calculated.

EFFECT OF EXTERNAL FIELDS ON MAGNETIZED ROTORS

A properly magnetized rotor of course must be immersed in an external field with which it reacts in order to produce mechanical torque. This external field, however, tends to alter the intrinsic induction of the rotor along minor hysteresis loops. For example, a rotor having an intrinsic induction B_{ix} corresponding to point S_1 on the major hysteresis loop in Figure 6A is immersed in an external field H_u. The relative directions of B_{ix} and H_u may vary from alignment to opposition as indicated by Figures 6B and 6C. In Figure 6B the magnetizing force is increased and the material performance follows the minor loop S_1S_2, returning to S_1 if H_u is reduced to zero. When, as in Figure 6C H_u opposes B_{ix}, the path follows the major loop from S_1 to S_4, but, if H_u is reduced to zero, the path now becomes S_4S_5. Thus the intrinsic induction is permanently reduced to a value corresponding to S_5, and further demagnetization will not occur unless the rotor is exposed to an external field greater than H_u and in opposition to the intrinsic induction. It also has been shown experimentally that, if the rotor has been demagnetized to S_5 as in Figure 6C, no further reduction will occur in the condition shown by Figure 6D. If the minor hysteresis loops which determine points such as S_2 and S_5 are not available from ring-sample tests, they can be closely approximated for high-coercive-force materials by drawing lines parallel to the tangent to the major loop at the point of residual induction (B_r).

CALCULATION OF MECHANICAL TORQUE OF A ROTOR

The intrinsic induction, B_{ix}, determined by the foregoing analyses for an elliptic-spheroid rotor, is by definition the magnetic moment per unit volume, M.[5] The mechanical torque of the rotor can be calculated from this moment, M. In practical designs the value of B_{ix} used for this purpose should be the minimum expected in service as determined by the relation of it to the field H_u, where H_u produces the strongest demagnetization effects as in Figure 6C.

With this value of B_{ix} selected, the magnetic moment in maxwell-centimeters is

$$M=B_{ix}\times(4/3)\pi a^2c \tag{9}$$

where $(^4/_3)\pi a^2c$ is the volume of the elliptic spheroid. The mechanical torque for the general case of the elliptic spheroid is therefore

$$\boldsymbol{T}=\frac{\boldsymbol{M}}{4\pi}\times\boldsymbol{H}_u \tag{10}$$

where $\boldsymbol{T}$ is the torque in dyne-centimeters, $\boldsymbol{M}$ is the magnetic moment in maxwell-centimeters, and $\boldsymbol{H}_u$ is the operating-field intensity in oersteds. In most practical applications motion is so restricted that only coplanar components of vectors $\boldsymbol{M}$ and $\boldsymbol{H}_u$ can produce motion. A discus-

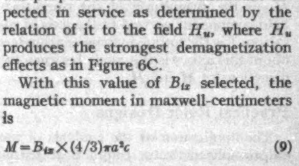


Figure 5. Graphical determination of the magnetizing force in an elliptic-spheroid rotor from the major hysteresis loop

Table I. Permanent-Magnet Materials

Number	Alloy Designation	Coercive Force, Oersteds	Residual Induction, Gausses	Density, Grams Per Cubic Centimeter	Mechanical Properties	Method of Fabrication
1	Chrome steel	63	9,000	8.20	Hard, strong	Hot forge, cast, machine
2	Tungsten steel	70	10,300	8.18	Hard, strong	Hot forge, cast, machine
3	Comol	220	10,000	8.15	Hard, strong	Hot forge, machine, cast
4	Cobalt steel	240	9,500	8.16	Hard, strong	Hot forge, machine, cast
5	Copper–nickel–iron	300	7,200	8.62	Ductile	Cold roll, machine punch
6	Alnico V	525	12,500	7.30	Hard, brittle	Cast grind
7	Copper–nickel–cobalt	710	3,400	8.30	Ductile	Cast, cold roll, machine
8	Sintered oxide	900	1,800	2.76	Hard, brittle	Mold, sinter
9	Cobalt platinum	2,700	4,500	18.0		
10	Silver–aluminum–manganese	6,000*	550	9.00	Ductile	Cold roll, machine punch

* Demagnetizing force required to reduce the intrinsic induction to zero, usually denoted by jH_c

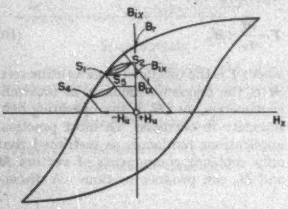
sion of this departure from the electromagnetic system of units is found in Appendix II. Thus equation 10 can be simplified to the following scalar form:

$$T = \frac{M}{4\pi} H_u \sin\theta \tag{11}$$

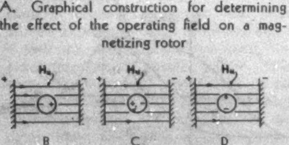
where M is the magnitude of the magnetic moment determined from equation 9 and is directed along the magnetization axis, H_u is the magnitude of the operating-field component normal to the axis of rotation, T is the torque in dyne-centimeters about this axis, θ is the angle between the directions of $\boldsymbol{M}$ and $\boldsymbol{H}_u$.

Practical Rotor Designs

The application of the analysis of the elliptic-spheroid rotor to practical instrument-rotor designs serves to explain the use of this method of approach in selecting the proper permanent-magnet material. In a specific design, the size of the instrument and therefore the permanent-magnet rotor usually is determined by the space limitations of the instrument application. Cylindrical rotors one centimeter long and one-half centimeter in diameter, magnetized diametrically and pivoted on the cylinder axis, may therefore be used in considering designs made of two materials, sintered oxide and silver–aluminum–manganese, which are well adapted to instrument rotors.



A. Graphical construction for determining the effect of the operating field on a magnetizing rotor



B, C, D. Possible relative directions of the intrinsic induction of the rotor and the operating field

Figure 6

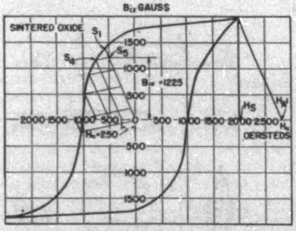


Figure 7. Graphical construction for determining the intrinsic induction of a one-half-by-one-centimeter cylindrical sintered-oxide rotor

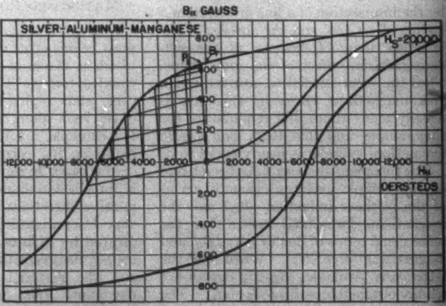


Figure 8. Graphical construction for determining the intrinsic induction of a one-half-by-one-centimeter silver–aluminum–manganese rotor

The elliptic spheroid which approximates this shape is the prolate form in which the direction of magnetization is normal to the generating axis and the ratio of major to minor axis, $c/a = 2$. From Figure 4 the demagnetizing factor $\boldsymbol{K} = 0.41$. This factor then is applied to the hysteresis-loop data obtained from ring-sample tests for sintered oxide in Figure 7 and for the silver alloy in Figure 8. It will be noted that these data are in terms of the intrinsic induction, B_i, and the magnetizing force, H, rather than the more usual B–H relationships. The relative positions of the B–H and the B_i–H curves are shown in Figure 1B for the silver alloy.

In Figures 7 and 8 graphical constructions following the procedure previously explained for the general case of a rotor immersed in an opposed external field (Figure 6C) are used to determine the values of the intrinsic induction B_{ix} corresponding to various values of the external field H_u. In Figure 7, S_1, S_4, S_5 correspond to the same points in the general analysis of Figure 6A. The condition of this field in opposition to the intrinsic induction of the rotor is used, since it is assumed that the rotor is allowed to turn to the position at which this condition can occur.

From the values of B_{ix} thus obtained for sintered oxide and the silver alloy, the corresponding values of magnetic moment M then are calculated from

$$M = B_{ix} \times (2\pi a^2 c) \tag{12}$$

where $2\pi a^2 c$ is the volume of the cylindrical rotor or in terms of the dimensions chosen,

$$M(\text{maxwell-centimeters}) = \frac{\pi}{16} B_{ix} \tag{13}$$

These values of M for sintered oxide and the silver alloy are plotted in Figures 9 and 10 for values of the external field H_u. From equations 11 and 13, the mechanical torque for the rotor position at which $\theta = 90$ degrees is

$$T_{\theta=90°}\ (\text{dyne-centimeters}) = \frac{B_{ix}}{64} H_u \tag{14}$$

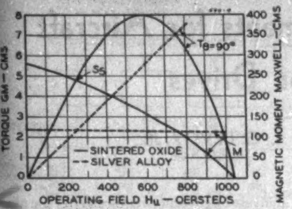


Figure 9. Magnetic moment and 90-degree torque available from a sintered-oxide rotor, and a silver–aluminum–manganese rotor of the same shape operated in field strengths to 1,050 oersteds

$$T_{\theta=90°}\text{ (gram-centimeters)}=\frac{B_{iu}H_u}{64\times 980}\qquad(15)$$

The torque values calculated from equation 15 also are plotted in Figures 9 and 10.

The comparison of the torque values for the two materials in Figure 9 shows that higher torques are available from sintered oxide for external fields below 770 oersteds, and for stronger fields the silver alloy is superior. As instrument designers are more often concerned with the torque per unit weight of the rotor rather than its absolute value, Figure 11 is given to compare the materials on this basis and further emphasizes the advantages of sintered oxide for field intensities below about 800 oersteds.

It is also interesting to note that, for field strengths between 3,000 and 6,000 oersteds, the silver-alloy rotor develops even higher torque per unit weight than the sintered oxide used with its most favorable field of 600 oersteds.

The instrument designer also will note that the values of torque to weight are considerably higher than those obtained in moving-coil designs. This is no doubt one of the chief reasons for the increasing popularity of moving-magnet instruments for applications in which sufficient operating field strength can be provided by stationary coils or other means.

In the preceding comparison of sintered-oxide and silver-alloy rotors, the operating field in which the rotor is immersed to produce torque has been assumed to be equal to the maximum field to which the rotor will ever be exposed. If, however, this operating field is exceeded because of overload currents in the coils producing it or other temporary conditions, the rotor will be further demagnetized. To take an extreme case, assume that the silver-alloy rotor while operating normally in a 500-oersted field may be subject to a momentary field of 5,000 oersteds in a direction to oppose the intrinsic induction of the rotor. Once the rotor has been demagnetized by this 5,000-oersted field, subsequent applications of it will cause no further demagnetization. The rotor magnetization therefore can be made permanent for all fields up to this value by subjecting it to an initial equivalent demagnetization. This, however, is accompanied by a reduction in the magnetic moment and torque from the values corresponding to the 500-oersted field. From Figure 10 the magnetic moment would be 77 maxwell-centimeters instead of 119, but a rotor having this reduced moment and operating normally in a 500-oersted field still has a 90-degree torque of 3.1 gram-centimeters. As this corresponds to a torque-to-weight ratio of about 17 millimeters, the rotor demagnetized to stand the momentary 5,000-oersted field should be satisfactory for most applications. This result exemplifies the value of the silver alloy in applications where a permanent magnet must withstand excessive demagnetizing fields.

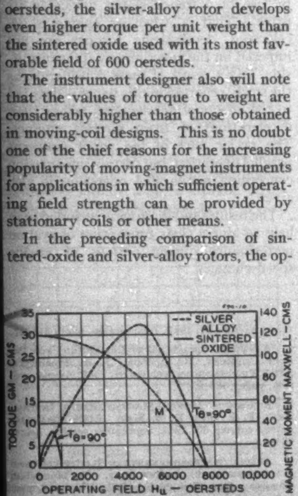


Figure 10. Magnetic moment and 90-degree torque available from the silver-alloy rotor operated in field strengths to 7,500 oersteds

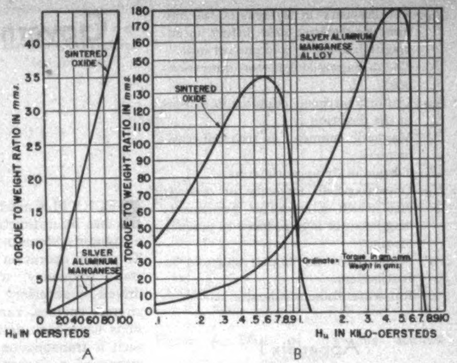


Figure 11. The performance of one-half-by-one-centimeter cylindrical rotors of sintered-oxide and silver – aluminum–manganese materials compared on the basis of torque-to-weight ratio for operating fields of 0 to 100 oersteds in A and 100 to 7,500 oersteds in B

Conclusions

The analyses presented are of value in determining the performance of permanent-magnet rotors for instruments. The assumptions made to simplify the treatment and particularly the use of the elliptic spheroid to approximate cylinders or other actual rotor shapes should be understood clearly by the designer applying the analyses to specific designs. He must continue to exercise sound judgment, especially in the selection of the elliptic spheroid which provides the closest approach to the magnetic conditions existing in the actual rotor under consideration. The writer has used the analyses presented for numerous instrument-rotor designs. The results obtained have agreed with experimental tests of samples of these designs within the accuracy limits of the tests and of the ring-sample data on which the calculations were based.

Materials other than the sintered oxide and the silver alloy already considered can be used for rotors and are preferable under certain conditions. Although economic as well as technical considerations should determine the final choice, the foregoing analyses can be of great assistance in making the selection, as the performance of a given rotor shape made of several different materials can be determined rapidly without recourse to building and testing samples of each. They may also serve as a basis for comparing moving-coil- and moving-magnet-instrument designs and for evaluating various rotor shapes. As the methods of calculation developed are based on well-established electromagnetic theory, it should be feasible to provide similar procedures for other permanent-magnet applications which will continue to increase both within and outside of the field of instruments and measurements.

List of Symbols

B_g—Air-gap flux density in gausses.

B_m—Flux density in the magnetic material in gausses.

H_m—Magnetizing force in the magnetic material in oersteds.

B_{im}—Intrinsic induction in the magnetic material in gausses.

l_m—Length along an assumed flux line in centimeters.

d—Air-gap length in centimeters.

H_x—Magnetizing force acting in the uniformly magnetized material in the direction x.

H_A—The intensity in oersteds of the uniform magnetizing field, before an unmagnetized rotor is immersed in it.
K—The demagnetizing factor (dimensionless).
B_{ix}—Uniform intrinsic induction in gausses in the direction x.
M—Magnetic moment in maxwell-centimeters.
T—Torque in dyne-centimeters.
H_u—Operating-field intensity in oersteds into which a saturated permanent-magnet rotor is introduced to produce torque.
c, a—Semiaxes of an elliptic spheroid in centimeters.
m—Ratio c/a (dimensionless).

Appendix I

For a prolate elliptic spheroid magnetized along the c and a axes, respectively, in Figure 3A, the demagnetization factors are:[4]

$$K_c=\frac{1}{(m^2-1)}\times\left[\left\{\frac{m}{\sqrt{m^2-1}}\log_e\left(m+\sqrt{m^2-1}\right)\right\}-1\right]$$

$$K_a=\frac{m^2}{2(m^2-1)}\left[1-\frac{1}{m\sqrt{m^2-1}}\times\log_e\left(m+\sqrt{m^2-1}\right)\right]$$

$$m=c/a$$

For an oblate elliptic spheroid magnetized along the C and A axes, respectively, in Figure 3B, the demagnetization factors are:[4]

$$K_c=\frac{1}{(1-m^2)}\left[1-\frac{m}{\sqrt{1-m^2}}\sin^{-1}\sqrt{1-m^2}\right]$$

$$K_a=\frac{m}{2(1-m^2)}\left[\left(\frac{1}{\sqrt{1-m^2}}\sin^{-1}\sqrt{1-m^2}\right)-m\right]$$

$$m=c/a$$

Appendix II

If M' is the magnetic moment in electromagnetic units (poles times centimeters), and H is the field intensity in oersteds, $T=M'\times H$ gives torque in dyne-centimeters. Now M' has the dimensions unit poles times centimeters, and, since 4π maxwells of flux emanate from a unit pole, the following equality may be written:

$$M'\text{ unit poles}\times\text{centimeters}=M\text{ maxwells}\times\text{centimeters}\times\frac{1\text{ unit pole}}{4\pi\text{ maxwells}}$$

whence

$$M'=\frac{M}{4\pi}$$

Thus $T=\frac{M}{4\pi}\times H$ will give the torque in dyne-centimeters if M is in maxwell-centimeters, and H is in oersteds. Permeameter values of B_i are measured in gausses or maxwells per square centimeter. But this B_i value is identical to maxwell times centimeters per cubic centimeter, or the magnetic moment in maxwell-centimeters per unit volume. Thus for uniformly magnetized rotors it is convenient to modify the electromagnetic units as given in equations 10 and 11.

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Governor Requirements for Aircraft Alternator Drives

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RECENTLY much engineering thought has been directed toward the use of a-c power systems in very large aircraft.[1,2] To permit operation at substantially constant frequency, when generators are driven by accessory drive shafts of main aircraft engines, variable-ratio transmissions have been designed. The ratio of such a transmission may be varied by means of a governor which maintains generator speed within a narrow range while the aircraft engine speed varies over a wide range. The engine speed range in typical cases may be three to one or greater. The frequency of a typical a-c system as now designed for large military aircraft must be held within about five per cent of normal, except during unusual transient conditions, when somewhat greater variations are permissible. When alternators are to be operated in parallel, differences in engine speeds should not be permitted to cause loss of synchronism of the generators.

The requirements for governing the variable-ratio transmissions differ in several ways from governor requirements for ordinary prime movers for industrial and central-station generators. In the aircraft systems considered, the prime mover is the main airplane engine which drives the propeller. This may be 100 times as powerful as the generator and will vary in speed over a wide range independently of the generator's requirements. Rapid changes in engine speed may be encountered. These conditions indicated that analysis of governor requirements for aircraft alternator drives would involve special study.

As a part of the development program for certain military aircraft, a study was undertaken to establish performance specifications for governors for variable-ratio transmissions. Some of the results of this study are presented in this paper.

The action of the governors should be sufficiently rapid so that the transmission ratios will follow changes in engine speeds closely enough to prevent loss of synchronism or undue variations of frequency. The rates of acceleration or deceleration of the engines determine the response which a governor must have to operate successfully. The effect of sudden acceleration of one engine was investigated for a variety of operating conditions. Accelerations are considered to affect performance more adversely than decelerations, because under transient conditions acceleration of a generator tends to increase its electrical load, whereas deceleration tends to reduce this load. Also, when one generator of a group of paralleled generators is decelerated, its effect on frequency and synchronism is minimized by use of a free-wheeling device in its drive. That is, when an engine is decelerated, decelerating torques are not imposed on the generator by its transmission. As a result of these considerations the study reported in this paper is devoted to the effects of acceleration rather than decelerations of main aircraft engines. The major part of the paper concerns parallel operation, but certain information concerning nonparallel operation is also given.

The results and discussion included may help to give a clear conception of system performance during periods of engine speed changes.

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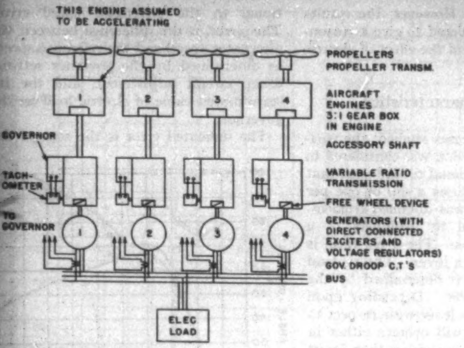

THIS ENGINE ASSUMED TO BE ACCELERATING
GOVERNOR
TACH-OMETER
TO GOVERNOR
1
2
3
4
PROPELLERS
PROPELLER TRANSM.
AIRCRAFT ENGINES 3:1 GEAR BOX IN ENGINE
ACCESSORY SHAFT
VARIABLE RATIO TRANSMISSION
FREE WHEEL DEVICE
GENERATORS (WITH DIRECT CONNECTED EXCITERS AND VOLTAGE REGULATORS)
GOV. DROOP C.T'S
BUS
ELEC LOAD

Figure 1. Schematic diagram of a-c power-supply system for airplane

System Arrangement

Figure 1 is a schematic diagram illustrating the arrangement proposed for operating four 40-kva 30-kw 6,000-rpm a-c generators in parallel for supplying 208-wye/120-volt three-phase 400-cycle power for use on an airplane. Each alternator is driven by a variable-ratio transmission, which in turn is driven from the main airplane engine.

Such a transmission may take any of a number of forms. One form consists of an oil pump with continuously variable stroke and a hydraulic motor driven by the variable oil flow. The stroke of the pump is varied by a servomechanism controlled by the governor. Each transmission is driven from an accessory drive shaft of a main aircraft engine. The engine rating is, of course, many times the rating of the alternator and transmission. Each transmission is controlled by its governor which operates to maintain alternator speed in spite of variations in engine speed. A free-wheeling device is included in the output shaft of each transmission. Each governor operates from the speed indication of a tachometer connected to the driving end of the free-wheeling device. An electric power-measuring circuit using a current transformer and a potential connection in each alternator output circuit is connected to the governor in such a way as to cause the generator speed to be reduced somewhat (droop) as the output is increased. Generators are controlled by individual voltage regulators. These regulators are connected to hold constant voltage and to divide reactive kilovolt-amperes properly among generators operating in parallel. Switching equipment in the electric-power circuits is not shown on the diagram.

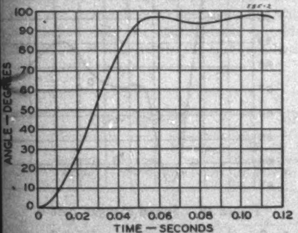


Figure 2. Angle between generators, case 1

Angle shown is the electrical angle between the alternator of the accelerated engine and the other three alternators

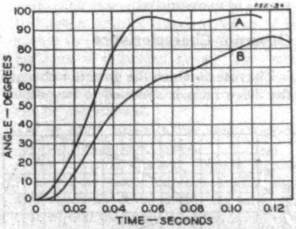


Figure 3. Effect of slip in drive

Angle shown is the electrical angle between the alternator of the accelerated engine and the other three alternators

A—Case 1; no slip in drive

B—Case 2; one-per-cent slip at full load

Engine Acceleration

If the engine speed changes very quickly, the governors cannot be expected to maintain absolutely constant speed on the alternators; instead, the alternator speed will change somewhat until the governors can restore normal frequency. If one engine (say number 1, Figure 1) accelerates while the speed of the other engines remains constant, the accelerated alternator will tend to pull away from the other alternators and may pull out of step. The governor should act sufficiently quickly to prevent the accelerated alternator from pulling out of step.

In all cases studied, one engine was accelerated at a rate of 2,150 rpm per second which was assumed to be the maximum possible. This value was determined by applying rated engine torque to the propeller inertia of a typical engine-propeller combination for a large airplane. The corresponding accessory-drive-shaft acceleration is 6,450 rpm per second. This value is probably much higher than any acceleration which will be encountered in normal operation. The engine acceleration was assumed to appear instantly. In practice the maximum acceleration probably will not appear instantly; the assumption made tends to make the results conservative.

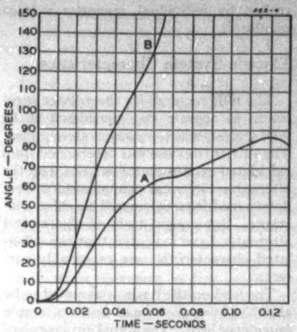


Figure 4. Effect of increasing applied acceleration

Angle shown is the electrical angle between the alternator of the accelerated engine and the other three alternators

A—Case 2; 6,450 rpm per second applied to alternator

B—Case 3; 14,300 rpm per second applied to alternator

The acceleration is considered to be sustained throughout the short time intervals investigated. It was necessary to study only the first few tenths of a second after the sudden appearance of acceleration, since synchronism was either lost or definitely established during this time.

In practice, the accelerations will not last indefinitely, and so the calculations are conservative in this regard.

Operating Conditions

A variety of initial operating conditions was investigated as outlined in the list of cases, Table I. Thus the effect of various factors, such as engine input speed, electric load, parallel versus nonparallel operation, governor action, drive slip, was investigated.

Each drive is considered to be controlled by an individual governor with an individual droop circuit for division of load. The load on paralleled generators was assumed to be balanced prior to the disturbances studied.

The voltage was considered to be controlled by individual generator voltage regulators.

Electric-System Characteristics

The time required for the voltage regulators to operate was considered to be 0.02 second, which is conservatively long. The exciter response was determined from calculated exciter characteristics, and the alternator electrical characteristics were determined from calculated machine constants. Subsequent tests on exciter and alternator have indicated that the calculated characteristics are reasonably correct.

The load on the bus was assumed to be at 0.75 power factor and to be a simple impedance load. The actual airplane electric load will consist of a mixture of motors and static loads. However, the results obtained are considered to give a reasonably accurate idea of the effect of electric load.

Transmission Characteristics

In most of the cases studied, the variable-ratio transmission was considered to have a slip proportional to load such that full-load output causes a slip of one per cent. This value was obtained from information supplied by designers of a typical transmission. The drive ratio is varied by moving a lever. The no-load ratio of the drive is determined by the position of this lever. Depending upon the position of this lever with respect to neutral, the drive will operate either in underdrive (output speed less than input speed) or in overdrive.

Governor Characteristics

The rate at which the governor changes the drive ratio is assumed to be proportional to the alternator speed error. This error is the difference between the alternator speed and the reference speed, as determined by the governor setting, droop circuit adjustment, and the instantaneous value of electric load on the governor.

The indicated error is the sum of the

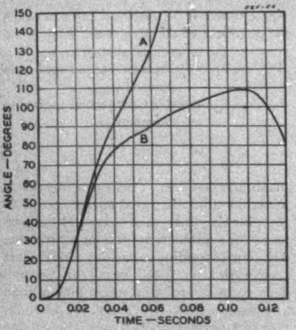


Figure 5A. Effect of governor action

Angle shown is the electrical angle between the alternator of the accelerated engine and the other three alternators

A—Case 3; no governor

B—Case 4; governor operating

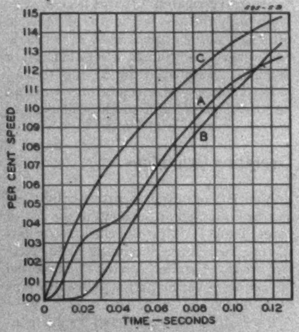


Figure 5B. Speed changes, case 4

A—Speed of alternator of accelerated engine

B—Speed of other three alternators

C—Speed *A* + drive slip = input speed × no-load ratio

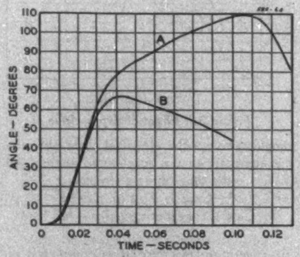


Figure 6A. Effect of increasing governor response

Angle shown is the electrical angle between the alternator of the accelerated engine and the other three alternators

A—Case 4; governor response = 0.0025 (ratio change per second) per rpm error

B—Case 5; governor response = 0.005 (ratio change per second) per rpm error

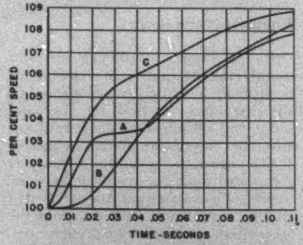


Figure 6B. Speed changes, case 5

A—Speed of alternator of accelerated engine

B—Speed of other three alternators

C—Speed *A* + drive slip = input speed × no-load ratio

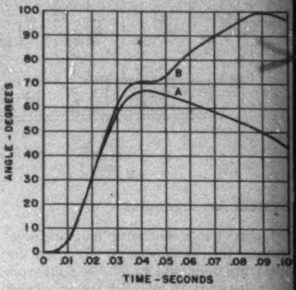


Figure 7A. Effect of electric load

Angle shown is the electrical angle between the alternator of the accelerated engine and the other three alternators

A—Case 5; no electric load

B—Case 6; electric load = 67 per cent per generator

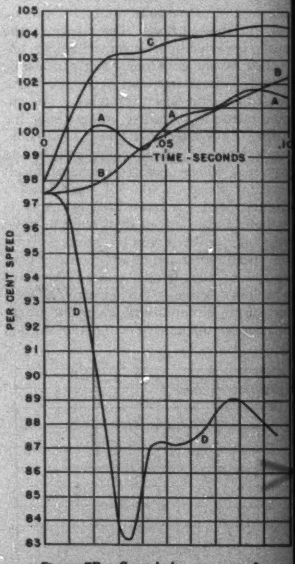


Figure 7B. Speed changes, case 6

A—Speed of alternator of accelerated engine

B—Speed of other three alternators

C—Speed *A* + drive slip = input speed × no-load ratio

D—Speed called for by governor droop circuit

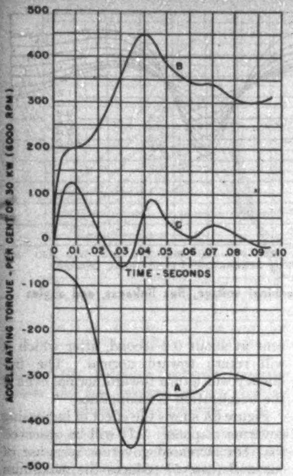


Figure 7C. Torques on generator, case 6

A—Electrical torque on generator of accelerated engine

B—Mechanical torque on shaft of same generator

C—Net torque on same generator

actual error indicated by the tachometer circuit and the apparent error indicated by the droop circuit. Such an apparent error occurs whenever the alternator power output increases (or decreases) as a result of transient conditions. Thus, an overload due to acceleration of an alternator causes the droop circuit to call for a lower speed and thus increases the signal to the governor in the direction of restoring correct speed. The correct speed in each case is considered to be the proper speed for the particular electric load under balanced steady conditions, as determined by the governor setting and droop-circuit adjustment.

In practice, there probably will be a maximum rate at which the governor can change the drive ratio, but it is assumed that the governor is so designed that this is reached only for speed errors outside the range encountered in the cases studied.

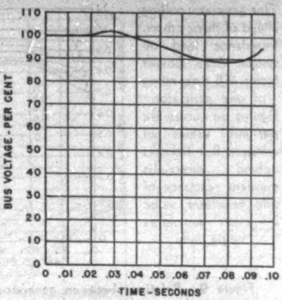


Figure 7D. Bus voltage, case 6

In each case, the governor is assumed to have a definite constant value of response in (drive-ratio change per second) per rpm of indicated error. The value selected is not the same in every case, and so the effect of changes in this value can be ascertained.

The drive ratio is the output speed divided by the input speed.

For the cases studied, there is a three-to-one gear ratio between engine shaft and accessory drive shaft. At an engine rpm of 900 the input speed is 2,700 rpm, so that for an output speed of 6,000 the ratio is 2.22. For this condition a rate of ratio change of 0.005 per second corresponds to a rate of alternator speed change of 13.5 rpm per second.

The governor is assumed to have no time lags in attaining the assumed response values. Actually there will be some time delay between the appearance of a speed error and the start of movement of the transmission ratio-control lever by the governor. Some idea of the effect of delays can be obtained by comparison of cases involving no delay and those including no governor action. These indicate that some delay is permissible and indicate approximately its allowable magnitude.

Cases Studied

The cases studied are outlined in Table I. A review of the results of the calculations for these cases form the basis of the conclusions given in this report.

The constants selected for the calculations are typical of a system for a large airplane using a-c power distribution. These constants are listed in Appendix III. Table II illustrates the manner in which the conclusions were obtained by comparing various results listed in Table I.

Sufficient cases have not been studied to be sure that the most severe conditions have been investigated; however, number 6 is considered to be fairly representative of a very severe case. This is the case of accelerating one engine at the maximum rate when operating at low speed, connected to a loaded alternator which is in parallel with three other loaded alternators.

Analysis of Results

The results of the cases studied have been plotted on Figures 2 to 8. These results may be analyzed by comparing various cases as outlined in Table II.

On several of the figures (Figure 2 for example) the electrical angle between generators is plotted. When the machines are operating at equal loads and excitations, as would be the case for normal operation, this angle is zero. That is, the rotors of the machines rotate at exactly the same speed and pass by a given point in each generator stator at exactly the same instant. If one generator is accelerated, its poles will pass any given point in the stator ahead of the corresponding poles in the other generators, so that the angle between the accelerated machine and the other machines is said to be increased from zero to a positive value. As this angle increases, the accelerated alternator delivers more load and may even furnish power to the other generators. The power transferred between generators tends to slow down the alternator of the accelerated engine and to speed up the other alternators, and thus resists the increase in angle.

Since the power transferred is only a very small fraction of the rating of the airplane engines, it will have practically no effect on the speed of the engines. However, it will cause changes in the slip in the transmissions, and it will cause the governor droop circuits to function in a

Table I. List of Cases

	Figure Numbers			Intial Conditions			Governor Characteristics			Results	
Case	Showing Angle	Showing Speed	Showing Other Quantities	No. of Generators in Parallel	Load Per Generator (Per Cent)	Engine Rpm	Slip in Drive at Full Load (Per Cent)	Full-Load Droop (Per Cent)	Response* (Ratio Per Sec) Per Rpm	Engine Acceleration Rpm Per Sec	Max Angle Between Generators (Degrees)	Max Speed Change (Per Cent)
1	2, 3			4	0	2,000	0		0	2,150	98	
2	3, 4			4	0	2,000	1		0	2,150	86	
3	4, 5A			4	0	900	1		0	2,150	Pulls out	
4	5A, 6A	5B		4	0	900	1	3.75	0.0025	2,150	109	16
5	6A, 7A	6B		4	0	900	1	3.75	0.005	2,150	68	9
6	7A	7B	7C, 7D	4	67	900	1	3.75	0.005	2,150	100	4.2
7		8		Nonparallel	0	900	1		0.005	2,150		12.2

* Governor response is measured in (drive-ratio change per second) per rpm of indicated alternator-speed error.

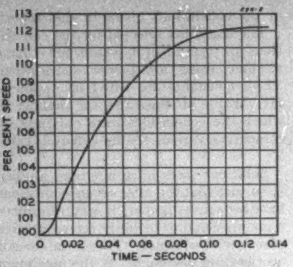
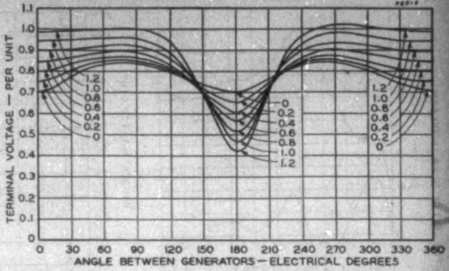


Figure 8. Generator speed, case 7

Speed returns to normal even if engine acceleration is sustained



One generator pulling ahead of three others. Impedance load on system, 0.75 power factor, 2.5 times rating of one generator

Figures on curves are per-unit values of armature flux linkages behind direct-axis transient reactance of one generator, value for other generators being unity

Figure 9. Relations between generator terminal voltage, flux linkages, and angles

direction to help maintain synchronism. The synchronizing torques also may cause the slower alternators to free-wheel at a speed above their drive output speed, thus tending to minimize alternator speed difference and keep the angle between generators within safe limits. Hence, the synchronizing torques between generators are very helpful in preventing loss of synchronism.

The electrical characteristics of the generators under transient conditions are such that the synchronizing torque increases with angle until an angle of about 130 degrees is reached. At this angle, the torque is several times normal. Beyond this angle the torque falls off rapidly, so that the machine is very likely to pull out of step if the angle exceeds 130 electrical degrees.

The angle for maximum transient torque is greater than 90 degrees because of the effect of flux trapped by the field winding. Typical transient torque–angle characteristics are given by Figure 10.

Table II. Schedule of Comparative Results

For Effect of	Compare	With
Slip in drive	Case 1 (no slip)	Case 2 (1% slip)
Applied acceleration	Case 2 (6,450 rpm per second acceleration applied to alternator)	Case 3 (14,300 rpm per second acceleration applied to alternator)
Governor action	Case 3 (no governor)	Case 4 (with governor)
Governor response	Case 4 (governor response—0.0025 per second per rpm error)	Case 5 (governor response—0.005 per second per rpm error)
Bus load	Case 5 (no load)	Case 6 (67% load per generator)
Nonparallel operation	Case 5 (parallel operation)	Case 7 (nonparallel)

In Figure 2 (case 1) the angle between machines does not exceed 100 degrees and returns toward zero after about 0.10 second. Hence synchronism is maintained. Since there is no governor in this case, the frequency, of course, continues to increase as long as the engine accelerates. Free wheeling permits the other three generators to be accelerated by electric power from the alternator of the accelerated engine.

Figure 3 shows the effect of slip in the drive. On curve *B* (case 2) the angle does not increase so rapidly nor reach so high a value as for curve *A* (case 1), so that there is less tendency to pull out and more time for governor action in this case than in the previous case. This shows that slip in the drive is helpful. See Table II.

Figure 4 shows the effect of increasing the acceleration applied to the alternator. On curve *B* (case 3) the angle increases rapidly beyond 130 degrees so that the generator can be seen to be pulling out of step as a result of the acceleration of the engine. It may be noted (Table I) that the engine acceleration is the same as for the previous case (curve *A*), but the drive ratio is higher, resulting in a higher acceleration of the alternator. In case 3 (curve *B*), the free wheeling and drive slip are unable to prevent pull-out.

In Figure 5A (case 4) the angle does not exceed 110 degrees and returns toward zero, so that the action of the governor, which was not present in the previous case, may be seen to be responsible for maintaining synchronism. (Table I shows that the initial conditions for this and the previous case are the same.)

In Figure 5B is shown the speed changes for case 4. The speed of all machines is increased, the other three machines being accelerated (free wheeling) by the electrical synchronizing torque. The effect of the slip in the drive may be observed by comparing curves *A* and *C* of this figure. The frequency may be seen to be approaching a maximum of about 116 per cent at about 0.2 second, after which it will return toward normal. The frequency will return toward normal even if the acceleration is maintained.

Figure 6A shows the effect of increasing governor response. It will be observed that the increased governor response of curve *B* (case 5) reduces the maximum angle reached.

It is evident that, when accelerations are less than the maximum possible, there will be more time for the governor to make corrections, so that a governor may have appreciable time lag and less than the maximum required response, if the acceleration does not attain its maximum value immediately. It is expected that in practice accelerations will not reach their maximum values instantly, so that the calculations may be conservative even though an actual governor will not attain its maximum response instantly. More complete data must be obtained before the net effect of delays in attaining maximum acceleration response and maximum governor response can be determined.

Figure 6B shows the speed changes for case 5. By comparison of this figure with Figure 5B (case 4) it will be seen that the greater governor response of case 5 reduces the change in frequency resulting from the engine acceleration. The frequency will return to normal sooner than in case 4.

Figure 7A shows the effect of electric load. This figure shows that the maximum angle is increased by the addition of electric load to the system. On curve *B* (case 6) the alternator does not pull out of step. However, the maximum angle reached in this case is quite large, (100 degrees), so that the generator probably would pull out if the governor response were appreciably less. Hence the response for this case (0.005 per second per rpm error) is just about sufficient to maintain synchronism in this severe case.

Figure 7B shows the speed changes for this case. The effect of the governor droop circuit is clearly shown by curve *D*, which shows the speed called for by this circuit as a result of the electric overload on the generator during the disturbance.

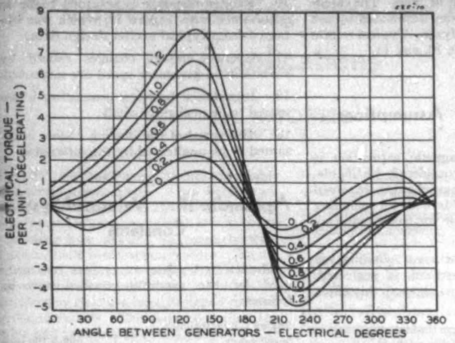


Figure 10. Relations between generator angles and flux linkages and the electrical torque on one generator

One generator pulling ahead of three others
Impedance load on system, 0.75 power factor, 2.5 times rating of one generator
Torque values are for generator which is being pulled away from others
Figures on curves are per-unit values of armature flux linkages behind direct-axis transient reactance of one generator, value for the other generators being unity
Torque values given on curves do not include torques due to amortisseur windings

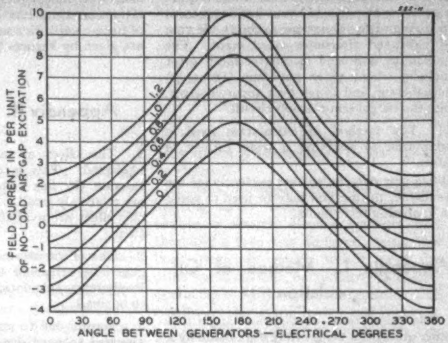


Figure 11. Relations between generator angles and flux linkages and the field current of one generator

One generator pulling ahead of three others
Impedance, load on system, 0.75 power factor, 2.5 times rating of one generator. Field-current values are for generator which is being pulled away from others
Figures on curves are per-unit values of armature flux linkages behind direct-axis transient reactance of one generator, value for the other generators being unity

The signal to the governor introduced by this circuit is seen to be greater than the actual speed change of the generator. The selected per-cent droop (3.75 per cent) is less than the value (five per cent) specified by the Army, so that droop circuit actually used may be even more effective if time delays do not hamper its action seriously. The initial speed is 97.5 per cent, because the initial load on the generators causes the droop circuit to establish a speed lower than the no-load speed, which was taken as 100 per cent.

The maximum speed change is less in case 6 (Figure 7B) than in the previous case, because the electric load tends to prevent overspeeding.

Figure 7C shows the torques acting on the alternator of the accelerated engine. The electrical torque (curve *A*) is seen to reach a value of over four times normal due to the angular displacement. This opposes the mechanical torque (curve *B*) exerted by the drive, so that the net accelerating torque (curve *C*) is relatively small and results in only a relatively small frequency error.

Figure 7D shows the bus voltage for this same case (case 6). It will be noted that, when four generators are operating in parallel, one generator may undergo a severe disturbance without causing more than about a ten-per-cent dip in the system voltage.

Figure 8 illustrates the performance during nonparallel operation, when the engine acceleration and governor characteristics are the same as for the preceding two cases. It will be noted that the maximum speed error is greater with nonparallel operation, because there is no synchronizing torque from other generators to minimize overspeeding. The frequency increases to about 112 per cent, after which it returns toward normal.

Conclusions

1. A free-wheeling device in the output shaft of each variable-ratio transmission is very helpful for maintaining parallel operation during periods of engine acceleration. Under favorable conditions such devices permit synchronism to be maintained without any governor action whatever.

As most accelerations are expected to be moderate and of short duration, they normally will produce only momentary unbalances in load division among generators, which will be corrected by governor action and by the cessation of the accelerations.

When free wheeling is employed, the generators usually will resynchronize themselves following a disturbance which causes pullout to occur.

2. Even a small amount of slip (say one per cent at full load) in the transmission is helpful for maintaining sychronism, during transients due to engine acceleration.

3. If the acceleration which appears at the alternator is increased, it becomes more difficult to maintain synchronism. For a given amount of engine acceleration, the alternator acceleration is greatest when the transmission is at maximum overdrive ratio.

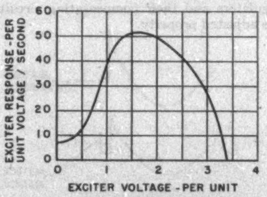


Figure 12. Exciter response—per-unit voltage per second

Exciter voltage is expressed in per unit of the value required for no-load air-gap rated-voltage excitation of the alternator

4. For the maximum accelerations considered, the effects of free wheeling and drive slip are not sufficient to maintain synchronism, so that reliance on governor action is necessary.

5. The effect of electric load on the bus is to increase the required governor response to maintain synchronism during periods of engine acceleration. This is true, because the load reduces the transient electrical synchronizing torque between generators.

6. Parallel operation tends to cause the frequency to be maintained within closer limits when one engine is accelerated, than would be the case for the same acceleration and governor response with nonparallel operation.

7. The rate of increase of acceleration is important in establishing governor requirements, as well as the maximum value of acceleration.

8. Time lag in attaining governor response should be kept to a minimum.

9. The governor droop circuit (which causes the alternator speed to droop with increased load) has a very beneficial effect in maintaining synchronism.

10. For the most severe case studied (case 6) the governor should attain its maximum required rate of ratio change in about 0.03 second to maintain synchronism. This maximum rate of ratio change is 5.3 per second for the assumed maximum engine acceleration of 2,150 rpm per second. The calculations indicate that to attain this rate

of ratio change in 0.03 second would require a governor response of about 0.005 expressed in (drive-ratio change per second) per rpm of indicated alternator-speed error. The maximum indicated alternator-speed error includes about three per cent (180 rpm) actual error, and 14 per cent apparent error, due to the governor droop circuit.

11. The method of calculation used is adaptable to studying a wide variety of cases.

When test data on system performance are available, the method may be used to assist in analyzing test results.

Appendix I. Method of Calculation

The calculations of electrical angle and other quantities versus time were made by a step-by-step process. At each value of time the rates of change of angles, speeds, generator flux linkages, transmission ratios, and exciter voltages were determined. These rates of change were assumed to remain constant for a short interval of time and the increments in these various quantities thus determined. By adding these increments to the original values, the angles, speeds, generator flux linkages, transmission ratios, and exciter voltages after the time interval were calculated. By making use of these new values and the constants of the system, rates of change for the next interval of time were determined. The process was repeated continuously, beginning with the time of first appearance of engine acceleration and continuing until the behavior of the system was ascertained.

In determining the rates of change of the quantities mentioned, certain other quantities, such as terminal voltage and torques, were calculated and plotted. The rates of change were determined using the constants given by Appendix III. The calculations for these rates were made on the basis of the assumptions listed in Appendix II.

The time intervals employed in making calculations in all cases were only 0.005 second or less. The interval used was determined by repeating calculations for one case with successively smaller intervals until further reduction in the interval produced substantially no difference in the result obtained.

It was found convenient to plot the calculated relations between terminal voltage, electrical angle, electrical torques (except amortisseur torque), generator flux linkages, and generator field currents, prior to making the step-by-step calculations, as these relations were independent of time. The calculations for these relations were aided by use of the a-c network analyzer. Typical results are given by Figures 9, 10, and 11.

Appendix II. Assumptions

1. The effect of magnetic saturation is neglected. This is considered justifiable, because the flux-linkage changes involved are relatively small. Methods for including this effect are available for cases requiring them.

2. The effect of amortisseur windings on generator armature currents is neglected. Preliminary calculations showed this effect to be small.

3. Torque due to amortisseur windings is assumed to vary directly with the rate of change of electrical angle with respect to terminal voltage, to be unaffected by rotor angular position, and to vary directly as the square of terminal voltage. Preliminary calculations indicated that this assumption is reasonably correct for the range of speed differences involved.

4. Voltages due to rates of change of direct- and quadrature-axis armature flux linkages are neglected. This assumption is justifiable, because these voltages are small compared to those resulting from rotation.

5. Generator friction, windage, core loss, and exciter torque are neglected.

6. Deviations in speed up to about ten per cent are assumed to have no effect on machine reactances or the ratio between power and torque. The effect of speed variations on terminal voltage is considered, however.

7. Alternators, voltage regulators, and governors are assumed to be identical so that several machines operating in parallel may be lumped into one, provided their engine speeds do not differ.

8. The rate at which the governor changes the drive ratio is assumed to be proportional to the alternator-speed error, within the range of speed changes involved.

9. Voltage-regulator action for small voltage errors (up to three per cent) is neglected. For greater voltage disturbances, the regulators are assumed to act, but to delay exciter response for 0.02 second. The effect of reactive cross-current compensation is neglected. This effect will be small if the regulators and their compensating circuits are adjusted properly.

10. Exciter response is assumed to be in accordance with Figure 12, which was obtained from typical exciter design data.

11. Exciter voltage changes caused by variations in generator speed are neglected.

12. Impedance between generators is assumed to be negligibly small.

13. The speed of the driving engine is assumed to be unaffected by the alternator.

Appendix III. Values of System Constants

The selected values of system constants used for the examples studied were as follows:

Engine Characteristics

Speed range	900–2,700 rpm
Accessory-shaft gear ratio	3:1
Accessory-shaft speed range	2,700–8,100 rpm

Alternator Constants

Rating:
40 kva, 30 kw, 6,000 rpm, 208 wye/120 volts, three phase, 400 cycles

Open-circuit field time constant	0.10 second
Amortisseur damping coefficient	7.0 (per-unit torque) ÷ (per-unit slip)
Inertia constant, H	0.21 second
Transient reactance, x_d'	0.16 per unit
Synchronous reactance, x_d	1.04 per unit
Quadrature reactance, x_q	0.58 per unit
Armature resistance	0.03 per unit

Exciter Characteristics

Response	Figure 12

Transmission Constants

Slip (when present)	0.010 per unit at 45-horsepower mechanical torque (6,000 rpm)
Input speed range	2,700–8,100 rpm
Output speed rating	6,000 rpm

Governor Characteristics

Speed droop (when present)	0.0375 per unit at 30 kw electrical torque (6,000 rpm)
Response	Up to 0.005 drive-ratio change per second per rpm, error

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2. Why Tomorrow's Planes Will Have A-C Electrical Systems, T. B. Holliday. *Electrical Manufacturing*, July 1943.

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A Current-Limiting Fuse for Aircraft Applications

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Synopsis: Although many fuses are available for aircraft applications, it has become increasingly evident that the trend to large aircraft electric systems necessitates a review of existing fuse devices, particularly with regard to their interrupting ability. Such a survey indicates many applications for an improved interrupting device. A new current-limiting fuse has been designed to meet the requirements. This paper describes the device and presents test data to indicate its suitability.

MUCH has been said about electric systems in aircraft including the history af their growth—voltage, available current, frequency, design, protection—as well as predictions of systems to come.[1,2] Articles, discussions, and lectures have indicated a trend that will require improved protective devices, particularly fuses. The fuse is a very widely used overcurrent protective device in aircraft electric systems today, because it provides maximum benefits for a minimum weight, space, and cost. Fuses which have proved satisfactory for present-day aircraft, however, should not be considered suitable for larger aircraft of the future. The definite trend to larger aircraft has resulted in three fundamental changes in the electric system:

1. There is an increasing number of operations being performed electrically, requiring larger amounts of available generated power.

2. Short circuits caused by battle damage in military airplanes or normal failures of connected equipment must be removed rapidly and satisfactorily to prevent system disturbances.

3. The circuits have become more complicated, requiring accurate, consistent, and correct fuse or protective-device operation.

The following general specifications for the required fuse and support are therefore proposed:

1. Adequate interrupting capacity.

2. Accurate and consistent time–current characteristics.

3. One-half cycle or less of arcing time.

4. Uniform contact resistance.

5. Vibration and shock resistance.

6. The foregoing characteristics to be affected only slightly by altitude up to 40,000 feet or ambient temperatures of −70 to +60 degrees centigrade.

7. Small size, compactness, light weight, and easy replacement.

Admittedly, a lot is required of a relatively simple device. Nevertheless, to meet these specifications, a new current-limiting fuse has been designed particularly for aircraft use. This paper discusses this fuse and presents information regarding applications.

Construction and Operation

For several years there has been available for central-station and industrial users a current-limiting power fuse.[3] This fuse, consisting essentially of a pure silver-wire element in an interrupting medium in the form of granular quartz, is unique in the way it operates on short circuits. The fuse limits the magnitude of the short-circuit current, under most conditions, to a value below that which would be produced in a direct short circuit. This action is summarized by the curves in Figure 2.

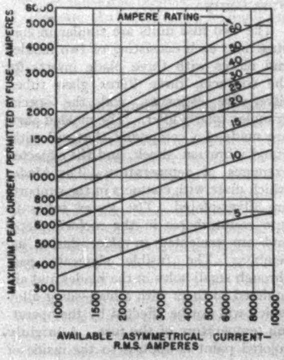


Figure 1. Current-limiting characteristics

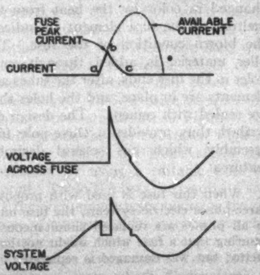


Figure 2. Wave forms of typical oscillogram of current-limiting fuse operation on a 60-cycle circuit

Short circuit starts at *a*, fuse melts at *b*, and arcing and interrupting complete at c

It was decided that this current-limiting action would be extremely desirable in aircraft electric systems, and therefore a fuse was designed, using this basic principle, which would meet the other specifications, particularly as to size, operating conditions, and vibration. The results are shown in Figure 3 and Figure 4.

The device is built at present in two frame sizes, one for a fuse of 30-ampere maximum rating and the other for a fuse of 60-ampere maximum rating. This division of ratings was arrived at after

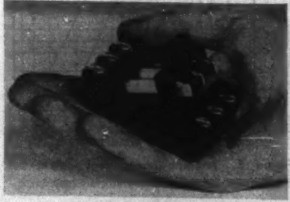
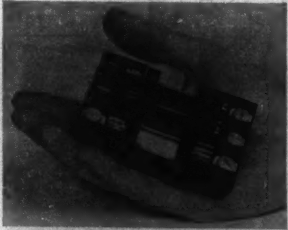
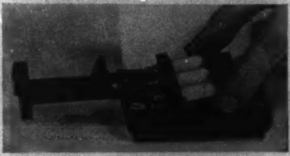


Figure 3. The new current-limiting fuse for aircraft applications

Thirty amperes, 208 wye/120 volts, 400 cycles. Fuse unit partially removed from holder



A. Fuse unit and latching bar are in place



B. Latch bar open and fuse being removed

Figure 4. The new current-limiting fuse for aircraft applications

Sixty amperes, 208 wye/120 volts, 400 cycles

Paper 45-88, recommended by the AIEE committee on air transportation for publication in AIEE TRANSACTIONS. Manuscript submitted November , 1944; made available for printing March 8, 945.

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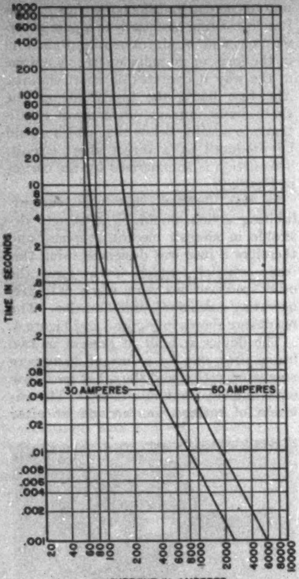


Figure 5. Melting-time–current curves for new current-limiting aircraft fuse

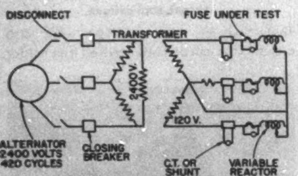


Figure 6. Test-circuit diagram

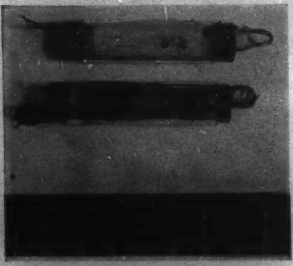
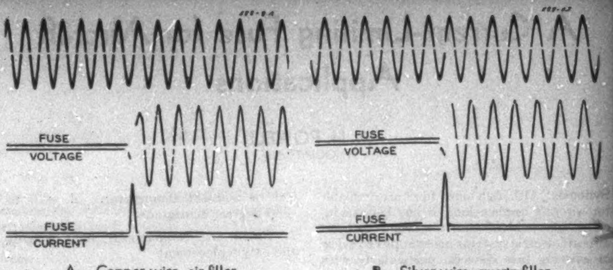


Figure 7. First sample fuses for preliminary tests, following interruption

Upper unit, silver wire, quartz filler. Lower unit, copper wire, air filler



A. Copper wire, air filler

Available current, 3,000 amperes; melting time, 0.00119 second; arcing time, 0.00059 second (Test 2, Table II)

B. Silver wire, quartz filler

Available current, 4,500 amperes; melting time, 0.00059 second; arcing time, 0.00030 second (Test 6, Table II)

Figure 8. Oscillograms for test samples shown in Figure 7

Tests made at 120 volts, 420 cycles

careful consideration of probable load requirements and design limitations of the maximum continuous current which could be carried safely by the terminals, contacts, and the fuse unit itself.

Fuse Units

The two fuse units are similar in construction, each consisting of two molded end pieces with three blade inserts for the contacts, three Pyrex glass tubes, silver-wire elements, and the special granular-quartz filler. The molded parts are made of a compound that will withstand vibration, shock, and the expected extremes of temperature. The blades which mate with contacts in the supports are silver-plated. The Pyrex tubes fit into counterbores in the molded pieces and are cemented in place during assembly. The fusible elements pass through small holes in the blades and are soldered to them with a lead–silver alloy which will not be affected by the operating temperature of the fuse. A brightly colored paint is applied to the inside of the glass tubes on the side towards the top of the fuse. The paint will be changed in color by the heat from the melting of the fuse element to indicate the blown condition of the fuse. The filler material is added through small holes in the fuse ends, after the tubes and elements are in place, and the holes then are sealed with cement. The design described thus provides a three-pole fuse assembly which has several desirable features:

1. When this fuse is used with proposed three-phase electric systems, the fuse units in all phases are replaced simultaneously, assuring that a fuse which might not have melted but was damaged is replaced.

2. There is no chance of one phase being accidently left open.

3. The phases are in separate isolated compartments, entirely preventing phase-to-phase short circuits within the device during the interruption.

The fuse element is made of pure silver wire with a reduced center section to limit the length which melts during interruption. There are, of course, many materials which could be used for the element, but silver was selected as the most suitable after careful investigation. Silver has a low specific resistance; thus a minimum cross section of wire will carry a given current, and there is a minimum amount of material to be dissipated during interruption. Furthermore, its melting and vaporizing action has proved more satisfactory in fuse operation than that of copper, which was also considered. Resistance to oxidation and corrosion are other characteristics in which silver is superior.

In the fuses for aircraft applications which are being considered in this paper, it is essential that ambient temperature have very little effect on the fuse time–current characteristics, for fuses which must co-ordinate may be in locations where ambient temperatures differ by 100 degrees centigrade. Thus, this is another reason why a high-melting-point element is superior to a low-temperature material such as zinc.

Many factors in the application of a

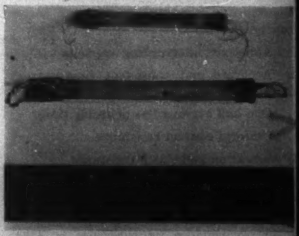
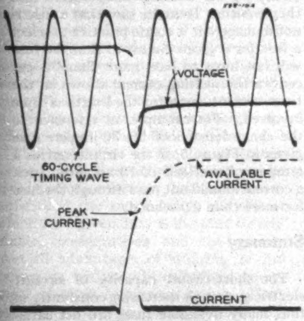


Figure 9. Sample fuses for second set of preliminary tests, after interruption

Upper unit rated 30 amperes; lower unit rated 60 amperes fuse dictate that it normally should be employed only as a short circuit rather than an overload protective device. This is discussed more fully later in the paper, but to meet this condition a fuse with "fast" characteristics is desirable, and this condition is obtained with the current-limiting fuse using a silver-wire element. Figure 5 shows typical time–current curves for 30- and 60-ampere aircraft fuse units.

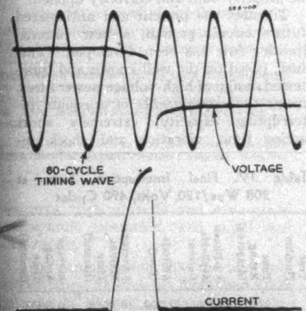
FUSE SUPPORTS

The fuse supports shown in Figures 3 and 4 are similar in that two molded end pieces are fastened to an insulated base to form the support for the terminals and contacts. Beryllium–copper spring contacts, silver-plated, are used in the 30-ampere holder in order to provide uniform contact resistance. The fuse unit is latched into the fuse support, to prevent loosening from vibration, by having the blades on one end of the fuse unit assembled under a pin at one end of the support, while a spring backed catch at the opposite end of the fuse support locks over a projection on the other end of the fuse unit. Thus the fuse unit operates similar to the blade of a disconnecting switch and may be readily removed from the support when in the "open" position. The catch must be released before the fuse unit can be moved to the "open" position.



A. Thirty-ampere fuse

Available current, 3,149 amperes; peak current, 1,640 amperes; melting time, 0.0067 second; arcing time, 0.0015 second (Test 5, Table III)



B. Sixty-ampere fuse

Available current, 3,149 amperes; peak current, 2,640 amperes; melting time, 0.013 second; arcing time, 0.0023 second (Test 6, Table III)

Figure 10. Oscillograms of d-c short-circuit tests made at 135 volts

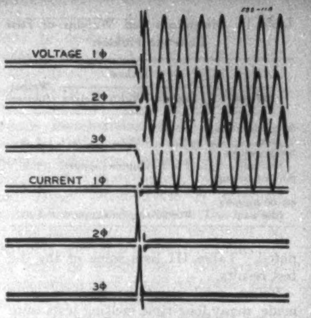
The 60-ampere support differs from the 30-ampere design, in that silver-plated copper contacts, backed by steel compression springs, are used. Furthermore, a hinged latching bar is arranged to swing into closed position after the fuse is inserted. The closing of the latching bar puts added pressure on the contacts, thus assuring uniform contact resistance, and holds the fuse in place against vibration and acceleration. The latching bar is held in place by a catch which is operated in the same manner as the catch described for the 30-ampere holder.

The over-all dimensions and weights of the fuse units and holders, given in Table I, indicate that the device is small and lightweight.

Tests

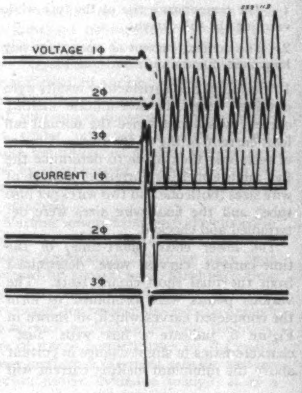
The current-limiting aircraft fuse was developed primarily for use on relatively high-voltage a-c electric systems. Specifically, the anticipated application was on a 208-wye/120-volt three-phase 400-cycle system. Therefore, the majority of the tests were made using this type of circuit. To check for operation of the fuses under other conditions, short-circuit tests also were made on 135-volt d-c circuits, and 120-volt 60-cycle a-c circuits.

Approximately 350 short-circuit tests were made during the development of the new fuse. Except for final check tests with a three-phase circuit, all tests were made with a single-phase 120-volt circuit, arranged as indicated in Figure 6, with a frequency of 420 cycles, which was the nearest available to 400 cycles. The initial series of tests was made using crude sample fuses to determine length of element, filler material, and other design limitations. Two of these samples after interruption are shown in Figure 7, and oscillograms for the two tests, Figure 8, indicate clearly the short arcing time obtained by using a suitable filler material. Table IIA lists the results of some of the preliminary tests made for the purpose of comparing the interrupting characteristics of silver and copper element in air and in quartz filler. Table IIB lists results of tests which demonstrate the current-limiting action of the fuses. Note that tests were made at currents up to 5,600 amperes and 40,000 feet altitude using a suitable pressure chamber. The arcing time was generally long and erratic with the air filler, but consistently short with the quartz filler. Thus the current-limiting fuse will meet the specifications for adequate interrupting capacity and short arcing time.



A. Twenty-ampere fuse

Available current, 3,100 amperes; melting time, 0.00071 second; arcing time, 0.0003 second (Test 2, Table IV)



B. Fifty-ampere fuse

Available current, 3,100 amperes; melting time, 0.0019 second; arcing time, 0.0003 second (Test 4, Table IV)

Figure 11. Oscillograms of final three-phase interrupting tests at 208 wye/120 volts, 420 cycles

Following the preliminary tests, a second series was made using samples with smaller-diameter tubes and elements designed in accordance with the results of the first series of tests. Typical samples for these tests are shown in Figure 9. The results were similar to the first series of tests and confirmed the suitability of the design. Tests also were made using the second set of samples, Figure 9, on a 135-volt d-c circuit. The results were very satisfactory. Figure 10 shows typical oscillograms of the tests, and again the very short duration of arcing should be

Table I. Dimensions and Weights of Fuse Units and Holders

Device	Inches: Length	Width	Height	Weight (Ounces)
30-ampere support	$2\frac{3}{4}$	$1\frac{11}{16}$	$1\frac{1}{4}$	1.9
5–30-ampere fuse unit	For 30-ampere support			1.1
60-ampere support	$3\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{9}{16}$	3.9
40–60-ampere fuse unit	For 60-ampere support			1.6

noted. Table III lists some of the d-c test results.

Before final short-circuit tests were made, many long-time melting tests were required in order to determine the exact size of fusible-element wire to obtain the required continuous-current ratings. Two factors govern this determination:

1. The temperature rise of the fuse while carrying the full current.

2. The melting current at some relatively long time, five minutes for example.

It was found that satisfactory results were obtained when the five-minute melting current was about twice the normal full load-current rating of the fuse. A series of tests was then made to determine the five-minute melting current of a range of wire sizes (both one and two wires per fuse tube) and the final wire sizes were determined and checked.

The lower ends (short-time) of the time–current curves were determined from the final short-circuit tests. The various points were combined to form the completed curves which, as shown in Figure 5, indicate a fuse with "fast" characteristics (a slight change in current above the minimum melting current will produce very rapid melting). The lower end of the curve is a straight line with a two-to-one slope.[4] Results of some of the final tests are listed in Table IV, and typical oscillograms are shown in Figure 11.

Vibration tests show conclusively that the particular filler material used has no detrimental effects on the elements. After 50 hours of vibration with a frequency of 10 to 55 cycles per second, no reduction in cross section of the element was observed. This may well be due to two factors in the design:

1. The special size and shape of the grains of the filler material.

2. The fact that the filler material is tightly packed in the fuse tubes.

Application

The subject of application of fuses in aircraft electric systems is too broad to be covered in this paper. However, a few suggestions as to the fundamental points are in order.

Good fusing practice dictates that a fuse should be used for short-circuit protection, not overload protection. There are other devices, such as automatic motor protectors[5] and temperature relays, which provide satisfactory overload protection. However, in aircraft systems it is essential that the circuits remain operable at all times, except when they are damaged, in which case the fuse must operate to disconnect that part of the system. The current-limiting fuse which has been described is ideally suited for circuit protection, for its current-carrying ability and time–current characteristics are similar to those of the conductor and are not appreciably affected by differences in ambient temperatures.

Thermal damage to a fuse element also must be considered when one is applying a fuse. Sufficient tests have been made to indicate that a change takes place in any element material when it is heated nearly to its melting temperature and then cooled. To make sure that a fuse is not damaged, it is a safe practice to select a fuse for a given circuit so that the fuse will not have to pass more than 75 per cent of the melting current shown on the time–current curve for the length of time involved. For example, in reference to the characteristics of the 30-ampere fuse given in Figure 5, if the circuit carries a temporary overload of 70 amperes, such a current should not pass through the fuse for more than 0.9 second.

Table III. Short-Circuit Tests at 135 Volts Direct Current

∮ Test Number	Fuse Rating (Amperes)	Available Current (Amperes)	* Peak Current (Amperes)	Melting Time (Seconds)	Arcing Time (Seconds)
1	10	480	296	0.003	0.0007
2	40	480	480	0.042	0.0022
3	20	1,675	870	0.0055	0.0009
4	50	1,675	1,580	0.022	0.0022
5	30	3,149	1,640	0.0067	0.0015
6	60	3,149	2,640	0.013	0.0023

∮ All tests made at 500 feet altitude.

* Actual maximum peak current permitted by fuse.

Table II. Preliminary Interruption Tests at 120 Volts, 420 Cycles, Single-Phase

A. To Compare Effect of Filler Materials

Test Number	Fuse Rating	Element Material	Filler	*Available Current	Altitude (Feet)	Melting Time (Second)	Arcing Time (Second)
1	20	Copper	Air	3,400	1,000	0.00089	0.00040
2	20	Copper	Air	3,000	40,000	0.00119	0.00059
3	22	Silver	Quartz	4,500	1,000	0.00059	0.00030
4	20	Copper	Quartz	3,400	40,000	0.00062	0.00030
5	20	Silver	Quartz	172	40,000	0.128	0.00035

B. To Indicate Current-Limiting Action. Silver Wire, Quartz Filler

Test Number	Fuse Rating	**Available Current	∮Peak Current	Closing Angle (Degrees)	Altitude (Feet)	Melting Time (Second)	Arcing Time (Second)
6	22	6,380	4,000	30	1,000	0.00059	0.00030
7	20	5,940	4,100	70	40,000	0.00050	0.00030
8	22	4,250	2,780	75	1,000	0.00094	0.00035
9	25	8,180	4,800	30	40,000	0.00055	0.00030

* Available current is maximum rms current which the circuit can produce in the absence of the fuse, calculated from the rms symmetrical current available and corrected for the actual closing angle.

** Available current is maximum peak current which the circuit can produce in the absence of the fuse, calculated from the rms symmetrical current available and corrected for the actual closing angle.

∮ Peak current is the maximum instantaneous current permitted by the fuse.

Summary

The short-circuit capacity of aircraft electric systems is increasing constantly so that many available fuses are not satisfactory for the duty imposed on them. Furthermore, higher voltages are being used in order to transmit more power with smaller conductors. A fuse is an excellent short-circuit protecting device, but it must be properly built and correctly applied.

To meet the present and anticipated future circuit growth, a new current-limiting fuse has been developed. This fuse, based on the well-known and time-tested design of high-voltage power fuses, meets the requirements of adequate interrupting capacity, extremely short arcing time, vibration and shock re-

Table IV. Final Interruption Tests at 208 Wye/120 Volts, 420 Cycles

Test Number	Fuse Rating (Amperes)	* 3-Phase Available Current	Altitude (Feet)	∮ Average Melting Time (Second)	Average Arcing Time (Second)
1	10	3,100	1,000	0.0003	0.0003
2	20	3,100	1,000	0.00071	0.0003
3	40	3,100	1,000	0.0012	0.0003
4	50	3,100	1,000	0.0019	0.0003
5	60	4,580	1,000	0.0018	0.0003
6	60	2,990	1,000	0.0038	0.0004

* Available current is the rms symmetrical current (average three phases) which the circuit can produce in the absence of the fuse.

∮ Melting time is average of three phases. The variation in time was caused by the closing angle of the three phases.

Measurement of Railway-Motor Temperatures in Service

J. W. TEKER
ASSOCIATE AIEE

THE EVER-INCREASING application of Diesel-electric locomotives to the many diversified traffic requirements of the railway systems over the nation is an acknowledgment of the versatility and effectiveness of this type of motive power. It brings to the steam road the high availability of the Diesel engine, the practical adaptation of which to railway-traction requirements is made possible through the electric transmission. The electric generator coupled to the Diesel engine enables the essentially constant torque and speed output of the prime mover to be converted to the widely variable range of torque and speed required for traction by means of electric motors geared to the locomotive drivers. This same transmission is used again when electric braking is applied to reduce or hold train speed.

The application of the Diesel-electric locomotive is then actually based on the speed-tractive-effort or braking characteristics of the transmission, the size of which for a given duty is dictated by economic considerations and the greater over-all advantages of utilizing to full extent an optimum standardized equipment of given continuous rating. However, tractive effort far in excess of continuous rating can be exerted by the smoothly applied motor torque to drivers with all the locomotive weight available for adhesion, and this capacity for overload is limited only by the heating of the windings.

Temperature of windings therefore is a prime consideration in the application of Diesel motive power wherever loads exceeding the continuous rating are encountered to see that the maximum permissible limits are not exceeded or maintained over a period of time to shorten unduly the insulation life. To this end, the silent movement of an ammeter needle over its scale is, psychologically to the man trained in steam operation, a poor exchange for the attention-compelling blast of a laboring steam-locomotive exhaust as an indication of exerted effort. There is an unquestioned finality when a steam locomotive stalls with its load that finds no adequate equivalent in the electric drive. The steady unemphasized beat of the Diesel exhaust continues, irrespective of the overload coupled to the locomotive which it moves with an apparent effortless ease with no sensible external impression of the winding's rising temperature or its proximity to the limit, until smoke and smell of burning insulation announce the damage to equipment.

The Diesel-electric locomotive does not know when to quit; nevertheless its ability to handle overloads is dependent upon the thermal capacity of the electric apparatus so that the duration, for which a given overload may be maintained with safety, is determined by the temperature of the windings preceding its application. Where ruling grades or speed of operation limit train weights, the load is generally below the continuous rating of the equipment, so that low winding temperatures provide a useful margin of overload capacity. This is an advantageous attribute of the electric drive in railway operation when it is correctly utilized.

It is essential to know motor temperatures just before a given overload to be able to determine the permissible duration for such duty. Temperature measurements taken in the intended service will be a check on the assumptions made during application study. It is often difficult to make proper assumptions of variables when making such studies for a difficult service. When steam helpers are required to move heavy trains over long grades, it is necessary at times to reduce Diesel-engine speed and power input to the motors in order to accommodate differences between the speed-tractive-effort characteristics of the steam and Diesel locomotives. If traction-motor blowers are belt-driven, the volume of ventilating air then is decreased, so that even operation at the continuous rating may be questioned. Temperature measurements are useful to obtain data and checks on such operation.

The use of cut-and-try overload application methods in service on narrow margins without knowledge of apparatus temperature is an uncertain undertaking the inadequacy of which may not be immediately evident, but will show up in time by increased maintenance cost and frequent motor or generator failures. Severe overheating in a single instance may be sufficient to shrink wedges and relax bands, without causing immediate failure, but subsequent movement of the winding under influence of vibration will cause the insulation to wear through and fail by short circuit or ground even before complete deterioration of insulation is achieved.

Various means have been developed in the past to give a continual indication of motor temperature, but none have been favored by general use. Until such time as temperature-indicating instruments are developed for railway use reliable enough to warrant general application, the measure of motor temperatures by the resistance method is the most reliable and accurate means available today. It is a recognized and familiar means of temperature determination by electric-apparatus manufacturers and is common on their test floors where the personnel is trained and skilled in its use.

This same method has been developed for the railway field by a series of evolutionary experiences until the technique and required skill have been reduced to a point where measurements can be made under these adverse conditions by an operator and the help of men unskilled in laboratory or test-floor methods. The results equal and sometimes surpass in speed, accuracy, and uniformity those obtained under more favorable conditions on the test floor, and it becomes a practical tool for general field use where questions pertaining to motor temperatures have a bearing on railway operation.

Method

The method selected for determination of average motor winding temperature is dependent upon the known change in electrical resistance of a copper conductor with temperature and is expressed by the

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sistances, high altitude and wide-range temperature operation, and small size and weight.

Tests demonstrated that the new fuse will interrupt dependably more than 4,000 amperes at 120 volts, 400 cycles, single-phase alternating current or at 120 volts direct current, with an arcing time of less than one-quarter cycle on the a-c circuit.

To obtain satisfactory operation of aircraft fuses, they should be used for short-circuit protection, not overload protection, and selected so that they will not be damaged by overloads.

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relation $T=(R/r)(234.5+t)-234.5$. The initial or cold resistance, r, of each component winding in question is measured after the motors have stood without power long enough to allow all motor parts to cool to a uniform ambient temperature, t, which is measured directly with mercury thermometers placed upon the motor parts and checked with each other and surrounding ambient temperature. The hot winding resistance, R, is measured at prearranged stops on the main line with the train and at the point where the temperature of the motors in the actual service is questioned. The temperature, T, is then readily evaluated from the corresponding cold resistance, r, at temperature, t.

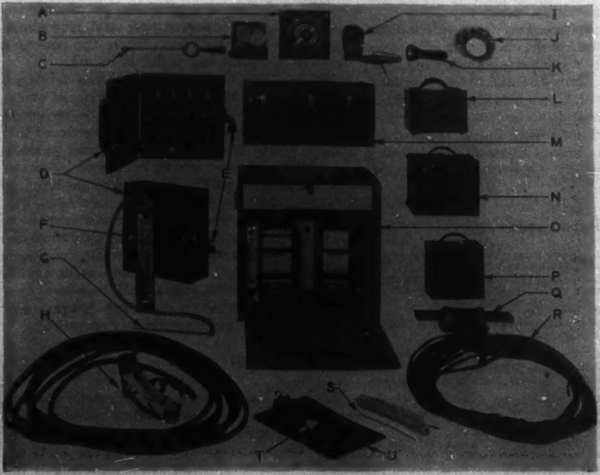


Figure 1. Instruments and special equipment required for measurement of railway-motor temperatures in service

Used to obtain operating data
A—Thermocouple selector switch
B—Hand tachometer
C—Hand pyrometer
D—Motor-field-resistance selector switches opened and closed
E—Padlocks
F—U-tube manometer
G—Static pressure tube
H—Armature-resistance contact yoke with flexible cable
I—Signal bell
J—Thermocouples
K—Flashlight
L—Thermocouple potentiometer
M—Special vibration-proof self-balancing double bridge
N—One-thousand-volt voltmeter
O—Special vibration-proof recording-chart ammeter and voltmeter
P—Millivoltmeter
Q—One-thousand-ampere shunt
R—Millivolt leads calibrated with shunt and meter
S—Centigrade mercury thermometer
T—Stop watch
U—Clip board

It is necessary to remove power from the motors and bring the train to a stop before these resistances can be measured. During this interval the motors are cooling, and the temperature of the winding as determined is for the instant of time when the resistance is obtained. This temperature is lower than the actual temperature of the winding at the instant when power was removed by the amount of cooling taking place during this elapsed time. However, by continuing to measure the resistance of the winding, as it cools with respect to a time started at the instant of power removal, it is possible to plot these values and draw a cooling curve through the related points. By extending this curve back to zero time, the most probable actual temperature of each winding is determined at the instant of power off and is well within the limits of accuracy for all practical purposes.[1]

Although temperature is the primary consideration determining motor life, it is expedient to plot the data in terms of temperature rise so that performance can be compared between successive tests under different conditions. Measurements, therefore, must be made of the ambient temperature during the test of the traction-motor ventilating air, as well as of the air surrounding the locomotive. The volume of ventilating air delivered to each motor being tested also must be determined, as well as the power input to the motors, so that rms current values can be calculated for the train tonnages hauled.

The success of the method outlined is dependent upon practical means for making the necessary measurements and upon a test crew organized and equipped to make these measurements without causing serious loss of time to the scheduled run of the train.

Instruments

The instruments and their connections are shown in Figures 1 and 2.

THE RESISTANCE BRIDGE

The traction motors in common use with Diesel-electric road locomotives are of the series type having armature, commutating, and series exciting fields of low resistance. The Kelvin double-resistance bridge circuit is ideal for the measurement of these low-resistance values. A vibration-proof galvanometer or its equivalent is required to obtain a balance on the bridge. This element of vibration requires careful attention in the selection and preparation of the instrument, as it is advantageous to keep the locomotive Diesel power plant running at idling speed during the stop for resistance measurement so that a quick train start can be made at the conclusion of measurements, and to keep the air compressors in operation to recharge the air-brake system after bringing the train to a stop. Even though the one power plant close to the instrument is shut down, enough vibration will come through from the remaining engines, through the couplers between units, to cause erratic behavior of the standard galvanometer when one is attempting to obtain a balance of the bridge.

A vibration-proof self-balancing portable instrument was constructed for this special purpose by the Erie works laboratory of the General Electric Company for the engineering department to be used in checking railway-motor application and has demonstrated ability in actual service to obtain data with speed, uniformity, and accuracy surpassing that obtained by previously used methods.

CONNECTIONS TO MOTOR FIELDS

The motor field windings are connected to the instrument with temporary wiring and suitable switches, so that resistance measurements can be made quickly. The instrument station should be located in the cab as close to the motors as possible so as to hold the interconnecting leads to a minimum. A pair of leads, a current and a voltage lead, is run to each terminal point of the winding and should be securely connected or soldered. The series field winding and one end of the commutating winding can be connected to the end of the motor cable in the junction box where they are joined with the locomotive power cable. They must connect to the motor end of the terminal to avoid the terminal contact resistance. The connection of the other end of the commutating winding can be made in-

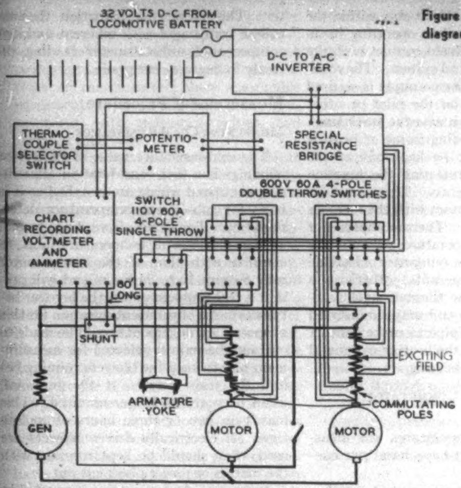

32 VOLTS D-C FROM LOCOMOTIVE BATTERY
D-C TO A-C INVERTER
THERMO-COUPLE SELECTOR SWITCH
POTENTIO-METER
SPECIAL RESISTANCE BRIDGE
600V 60A 4-POLE DOUBLE THROW SWITCHES
CHART RECORDING VOLTMETER AND AMMETER
SWITCH 110V 60A 4-POLE SINGLE THROW
80' LONG
SHUNT
EXCITING FIELD
ARMATURE YOKE
COMMUTATING POLES
GEN
MOTOR
MOTOR

Figure 2. Connection diagram for measurement equipment

side the motor where it joins the brush holder. These two instrument leads should be brought out of the frame without interfering with the motor inspection cover as it will have to be removed for armature-resistance readings and then quickly replaced. A hole may be drilled through a noncritical section of the frame to let these leads through, to be closed at the conclusion of the test. These leads should be run and secured alongside one of the main motor cable, as far as the junction box under the locomotive floor, where it can join the bundle of leads coming off the terminals and going to the instrument station. This bundle of instrument leads should have additional protection where it passes through and bends over structural members to avoid damage to the insulation.

Connections to Motor Armature

The armature resistance is obtained by selecting a span of the armature winding to which connection is made by contacts spaced apart by the desired number of commutator segments and held in fixed relationship by a special yoke applied by hand pressure to the commutator through the motor inspection opening.

This yoke has a locating lip to engage the undercut mica space between two adjacent commutator segments to align the contact points correctly on the segment at each end of the selected span of bars and prevent their coming in between two segments to cause erratic measurements. The number of segments included in the span should be as large as the space between brush holders permits without cramping the yoke, so as to obtain a maximum value of resistance for measurement. The contacts are individually spring-loaded and slide in parallel ways to accommodate slight inequalities in the hand pressure applied to the yoke.

Connection between contacts of the yoke and the instrument station is made through a multiple-wire flexible cable long enough to reach through a cab window down to the motors in the locomotive truck. This equipment is coiled and carried in the cab between stopping points for measurements.

Resistance Selector Switches

The switches are 600-volt four-pole double throw, with flexible jumpers connected around the hinge point of the blade. They should be completely enclosed with provision for padlocking the switch in the open-circuit position. This is a safety precaution, as the instrument leads are connected with the high-voltage power circuit when the locomotive is in operation, and will serve to isolate the instruments and personnel from harm. It also permits wiring to be installed during layovers between runs, thereby keeping the locomotive available for service while preparation for the test is being made. It also permits removal of instruments after a test run until results are checked. The switches should be located within reach of the instrument table so that the bridge can be switched from one connection to another in prearranged sequence.

Communication System

A signal system is necessary between the man at the instrument station and the men in position at the motors when measurements are in progress because of their remote location and the magnitude of noise level with Diesel engines idling. A push button fixed at the instrument station and a simple electric bell properly protected against injury during handling are used for this purpose, interconnected with flexible leads long enough so that they can be lowered from the cab to a man on the road bed. The signal code used is as follows:

One bell—make contact with yoke on armature.

Two bells—hold contact; measurement is in progress.

Three bells—remove contact.

An ammeter placed in the battery circuit of the bridge indicates the instant a circuit is established through the armature and informs the resistance bridge operator to proceed with measurement, while the man making the contact is informed to hold it by signaling two bells. A failure to establish contact with all four points on the commutator simultaneously is evidenced by failure of the ammeter to indicate if the current circuit is open or by an off-scale swing of the bridge if the voltage or drop circuit is open. In this case, the operator continues to call for contact by repeating the one-bell signal.

Arrangement for Power-Input Measurement

The power input to the motors is measured with a voltmeter and ammeter with respect to time, the interval of which is dependent upon the profile of the railroad and the operation being studied. This is a laborious and tedious procedure which may be eliminated by installing chart-recording instruments to keep a graphic record of the test. Recording instruments should be equipped with special marker pens, energized periodically by means of a Telechron-driven contact-making switch to put a reference mark on each graph. A push button also should be provided to enable operating the marker pens at will for special purposes, such as the passage of significant locations. In addition, the chart must be clearly marked with notes to aid analysis after these tests are completed.

The recording instruments must be shockproof-mounted to obtain a smooth graphic record. The indicating voltmeter and ammeter should be retained for a periodic calibration check of the recording instrument. All instruments must be secured to the cab structure to prevent displacement when curves at high speed are being negotiated.

The ammeter shunt must be connected to the motor power circuit on the low-voltage or grounded side of the circuit to minimize hazard to personnel. The leads between the indicating ammeter and shunt must be calibrated together with the shunt and recording instrument before being installed in the locomotive. One side of the voltmeter always will be on the high side of the power circuit and must be safeguarded.

1. With fuses small enough to prevent fire in case of accidental short circuit.

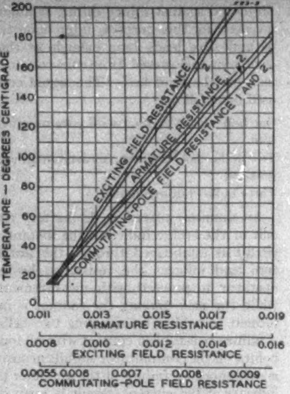


Figure 3. Typical temperature–resistance curves for motors 1 and 2

Resistance at 25 Degrees Centigrade

	Number 1	Number 2
Armature	0.01175	0.01190
Exciting field	0.00875	0.00890
Commutating pole	0.00605	0.00605

2. With a cutout switch in the event it is necessary to remove or make adjustments to the voltmeters.

A small rotary inverter operating on 32 volts direct current provides alternating current at 110 volts, 60 cycles, from 16 cells of the locomotive storage battery to operate the self-balancing bridge, the recording instrument, and the Telechron timer for the marker pens. The circuit between the storage battery and the inverter should be protected with fuses.

Installation of Thermocouples

Thermocouples made up from copper and copnic wire serve to measure the temperatures at remote locations inaccessible while under way, such as the roof and road-bed ambient temperature, traction-motor-armature and axle-bearing, frame, and air-out temperatures. Thermocouples are connected to a selector switch which becomes the cold junction and should be equipped with a thermometer so that the measuring potentiometer connected with it can be corrected for variations in temperature of the selector switch which may fluctuate with cab temperature.

The potentiometer may be set up in shockproof mountings so that the galvanometer can be balanced, or it may be connected with the balancing element of the special resistance bridge which is unaffected by vibration. This is feasible as thermocouple readings usually are taken while under way in between test stops.

The roof-air-temperature thermocouple fastened to a length of spring wire should project above the boundary layer, but care must be taken that it stay within the clearance diagram when operating in an electrified zone to avoid contact with the high-voltage overhead system. The road-bed-temperature thermocouple is secured to a step bracket on the pilot or other structure entering air near the track level. Thermocouples reading frame or bearing temperatures must be kept out of the wind stream by protecting the junction end from its influence. They must be secured in tight contact with the member to be measured. Thermocouples for roller-bearing temperatures should be clamped between the outer race of bearing cap if opportunity permits; otherwise, a spring wire with the thermocouple junction soldered to its end may be inserted through the grease pipe to make contact with the bearing or the bearing cap metal in contact with the bearing.

Measurement of Commutator Temperatures

Commutator temperatures are measured with a contact-type hand pyrometer. This is an open-junction thermocouple instrument with inherent ambient compensated millivoltmeter reading directly in degrees centigrade.

Measurement Procedure

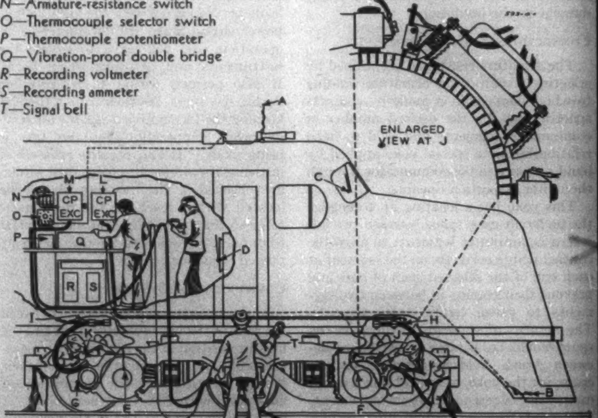
Measuring Cold Resistance

The cold-resistance value of the motor windings is a first consideration after instruments and wiring are installed as it is basis for subsequent temperature determination. To permit all windings to cool off to a uniform temperature and to equalize with that of the entire motor may require 12 to 24 hours and will present a real problem unless the layover between runs is of sufficient duration for this purpose. Arrangement should be made to cut out the motors selected for measurement and to keep the blowers running before the train arrives at the terminal, when they are no longer required. This may gain two or three hours of cooling time. If electrically driven blowers are used, they should be kept running with the motors or power plant cut out.

As soon as the locomotive is spotted in a final position for servicing, mercury thermometers can be applied to the frames, field coils, pole tips, armature core, and commutator risers. It is well to caution against the application of putty directly on the brush surface of the commutator, as it may present some difficulty in cleaning without at the same time destroying the commutating film, thereby altering conditions for subsequent tests. Comparative ambient temperature may be obtained by placing a thermometer on the track rail head with putty over the bulb, or by placing a thermometer in a small can filled with oil so as to stabilize fluctuation in air temperature when large doors are opened in the locomotive service shop or roundhouse, or

Figure 4. Position of personnel when taking temperature measurements

A—Roof-air-temperature thermocouple
B—Road-bed-air-temperature thermocouple
C—Windshield air thermometer
D—Traction-motor blower air-in thermometer
E—Pinion-end armature-bearing-temperature thermocouple
F—Commutator-end armature-bearing-temperature thermocouple
G—Axle-bearing-temperature thermocouple
H—Number-1-motor field-resistance leads
I—Number-2-motor field-resistance leads
J—Armature-resistance yoke
K—Commutator-temperature pyrometer
L—Number-1-motor field-resistance selector switch
M—Number-2-motor field-resistance selector switch
N—Armature-resistance switch
O—Thermocouple selector switch
P—Thermocouple potentiometer
Q—Vibration-proof double bridge
R—Recording voltmeter
S—Recording ammeter
T—Signal bell



when the wind is variable when the locomotive is standing in a railroad yard. Cold-resistance measurements can be started as soon as comparative observations of thermometers show reasonable agreement. Record the date, time, temperatures, with resistance values, and check at intervals.

When armature cold resistance is being measured, the armature yoke should be applied on several alternative segment positions available, and, after the armature thermometers are removed, the locomotive may be moved sufficiently to present different sections of the commutator, the measurements on which should check reasonably with one another. If a wide variation is detected, the reason for it should be ascertained and corrected. The section showing disagreement may be explored by making bar-to-bar measurements to see if a high-resistance fault exists in the armature windings or its connection to the commutator risers. Motors will operate without any visible sign of distress on the commutator and yet may have appreciable variation in bar-to-bar resistance; although this is permissible for operation, it would not be acceptable for a temperature test, as the data obtained may be erratic if the train happens to stop with this fault in the accessible section of the commutator for the temperature measurement. It may prove a wise precaution to bar-to-bar-test the armatures of the motors before selecting them for temperature tests, as a visual inspection will only detect faults which have progressed to an advanced stage.

Cold-resistance readings again should be measured at the conclusion of all testing and checked with the initial readings to ascertain that no changes had occurred during the testing period. For this purpose, resistance values should be evaluated at 25 degrees centigrade as a common basic temperature for comparison.

TEMPERATURE–RESISTANCE CURVES

The work of reading temperatures will be facilitated greatly by drawing temperature–resistance curves for each winding in each motor being tested (Figure 3). Since this curve is a straight line within the range of temperatures under consideration, it is only required to plot the cold-resistance values at their measured temperature and calculate the value of resistance for 200 degrees centigrade as being the extreme value when hot. A straight line is drawn through these two points, and any intermediate value can be read directly from the curve.

DETERMINATION OF COOLING-AIR VOLUME

The air delivered to the motors by the blower is best measured by drilling the commutator inspection cover to admit a static pressure tube into the commutator chamber, and then reading the air pressure in inches of water on a manometer. The readings should be taken at idling, one-half and full speed of the blower, and at the same time the speed of the engine should be measured. When tests are concluded, engine and blower speed again should be measured to see that conditions remained the same during the testing period. Record date, time, speed, temperature of air at blower intake, and barometric pressure, if the data are to be used for comparative reference.

A similar procedure for electrically driven blowers should be followed, except that speed would be dependent upon blower voltage instead of engine speed as with the belt-driven blower.

The volume of air to the motors is determined from a pressure–volume curve usually available for the type of motor being tested. If one is not available, it can be prepared by blowing a similar motor through a calibrated pipe to determine the volume delivered for corresponding pressures in the commutator chamber as outlined by blower manufacturer's testing code.

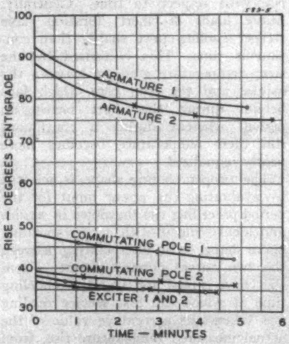


Figure 5. Typical cooling curves

Total train weight 1,224 tons (13 cars + locomotive) rms current 449 amperes for 67 minutes or total distance of 81 miles

O=motor 1 X=motor 2

Rises Based on 42 Degrees Centigrade

	Number 1		Number 2	
	Temperature	Rise	Temperature	Rise
Armature	135	93	131	89
Commutating field	89.5	47.5	81.5	39.5
Exciting field	80.0	38.0	79.0	37.0
Commutator	110	68	105	63

MAKING THE SERVICE TEMPERATURE MEASUREMENTS

Before the test run is made the locomotive should be moved from over the service pit onto a section of track similar to the main-line road bed. Assign the test crew to their stations, and outline the testing procedure and the duties for each station. The entire sequence of the test should next be rehearsed, including the making of measurements, and the entire operation timed from start to finish. This practice will prove invaluable to the men by relieving tension and instilling confidence and teamwork in preparation for the actual measurements on the main line.

The following program of events is performed in sequence (Figure 4):

1. Just before the arrival at the designated stop for heating measurements, a prearranged signal from the head end is given when power is no longer required to make the stopping point. Padlocks are removed from the switches, and all equipment is made ready.

2. As soon as power is shut off at the head end and the engines come to idling speed, a stop watch is started at the instrument station, and the electric-driven blower or the Diesel engine belted to the blower, as the case may be, is shut down completely.

3. As soon as the train comes to a stop, it is made safe (removal of reverser handle or other means to lock power off) by a man at the head end who then leaves the cab and takes a position on the road bed at the truck while two other men, one for each motor, climb under the locomotive and remove the motor inspection covers.

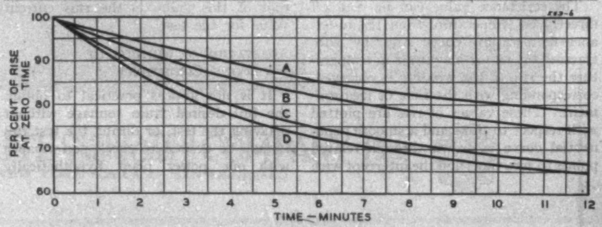
4. While step 3 is taking place, the two men at the instrument station unwind cables and pass the armature yoke, signal bell, and pyrometer down to the man on the road bed adjacent to the truck, who retains the bell and gives the resistance yoke to one man at the motors and the pyrometer to the other.

5. Resistance measurements are made in the following order by two men at the instrument station:

(a). Motor 1 commutating field, then exciting field, followed by the field measurements on motor 2.

Figure 6 (below). Average armature-cooling curves obtained from heat-run data

	Amperes	Rpm	
A	650	1,300	Continuous
B	675	778	Continuous
C	1,000	450	30 minutes
D	1,130	374	13 minutes



(*b*). Signal for armature contact to be made and held on armature 1 while commutator 2 temperature is measured. Signal as soon as resistance is obtained, and the man on the road bed will pass the yoke from motor 1 to motor 2 and the pyrometer from motor 2 to motor 1 and make a record of commutator temperature. As soon as contact is established on armature 2, the instrument station will acknowledge by signal to hold contact while resistance is measured, after which the concluding signal is given. Meanwhile record is made of commutator 1 temperature.

(*c*). The fields of motors 1 and 2 again are measured while the yoke and pyrometer are exchanged by the man on the track in readiness for repeating armature and commutator temperatures. At least three readings on fields and armatures of each motor should be obtained in six minutes time from the instant the power is off, which may be broken down into an average of two minutes to make the stop and get the first armature contact and four minutes for all subsequent measurements. As each resistance value is called off by the instrument operator, the other man notes the time and enters the value on a prepared data sheet.

6. As soon as measurements are concluded, the cables are pulled into the cab, motor covers are replaced, and both men climb from under the locomotive; when all is clear the shutdown engine or blower is started and the run is resumed.

7. The commutator temperatures which were recorded by the men on the track are transferred to the data sheet at the time values corresponding with the opposite motor's armature-resistance values.

8. During the run, and especially for a period of time preceding a stop for winding-temperature measurements, readings are taken and recorded in the log of air temperature on the roof and road bed, and at traction-motor blower intake. Readings also are made periodically of motor-frame, air-out, and bearing temperatures. The chart-recording instruments are inspected to see if they are inking, and calibration is checked with readings on the indicating instruments. At the head end of the locomotive, windshield temperature, speed, location on the railroad, and controller notch position are recorded with respect to time so that they may be related to the readings in the test log.

For the purpose of obtaining these readings, the test crew is reassigned to secondary duties, so that there is a division of labor, but co-ordination of all data at one point is insured. The make-up of the train in tons and number of cars for each test run should be recorded with the train identification and direction of travel.

Determination of Operating Temperature

The Cooling Curve

The resistance value can be read off directly as temperature from the resistance–temperature curve and by subtracting the motor-blower air-in temperature the rise of the winding is obtained, corresponding with the time of measurement. These values of rise are plotted with respect to time, and a smooth exponential curve is drawn through related points to zero time, and the intercept with the temperature axis is the most probable temperature rise of the corresponding winding at the instant of power removal (Figure 5). The importance of getting the first readings as soon as possible after power off becomes evident for it minimizes the extent of extrapolation of the curve.

The cooling-curve technique also is applied to the hand-pyrometer commutator-temperature readings to arrive at the probable rise just before power off.

The Use of Average Cooling Curves

Occasionally, circumstances will prevent immediate measurement of armature resistance and a prolonged cooling period will result before the first reading is obtained. The extrapolation of these delayed data to zero time is aided by the use of average armature-cooling curves (Figure 6). These curves are prepared from factory test data on the same type of motor for several different conditions of power input and are expressed in terms of per-cent temperature rise with respect to time. Generally, heavy loads of short duration have steeper cooling-curve shapes than continuous runs. This is caused by the steep temperature gradient between the copper and the iron core which lags behind during the short heating-up period, whereas during a continuous run their temperature becomes more nearly equalized.

The proper cooling shape is selected by evaluating the power input for the period preceding the shutdown in service and identifying it with a corresponding curve shape, or by interpolating between the two curves coming closest. From this curve is read, for the elapsed cooling time at which the first service reading was taken, the percentage value of the actual measured temperature rise, from which is prorated the 100 per cent value at zero time.

Determination of Rms Current

The rms current value is obtained from the chart made by the recording ammeter by dividing the graph into intervals of time, and the average current value for each interval is squared and multiplied by that time interval. The sum of these products is divided by the total time, to get the average current squared for the run. The square root of this value is the rms current value for the test.

Adaptation of Method to Varying Conditions

It is not always practical to obtain the full desired train tonnage without delaying the test, or during the test run it may be desired to check performance with one power plant hypothetically broken down. These situations can be approximated by purposely reducing the locomotive power by multiples of the number of motors until the desired prorated train tons per motor is obtained. The temperature measurements then are made under this artificial condition. For example, if two out of eight motors are cut out of a locomotive in an 18-car test train having a combined weight of 1,680 tons, the load per motor will be increased from 210 to 280 tons. The heating of the motors then would be equivalent to that of a 25-car train of 2,240 tons total weight.

The method, procedure, and equipment also are applicable to measurements of generator temperature which can be made in a multiple-unit locomotive by shutting down the one power plant for a few minutes to obtain measurements without the necessity of stopping the train.

The recording-chart instrument with calibrated instruments affords data on engine horse-power output by reference to a generator characteristic for the generator efficiency values over the operating range from which the horsepower input to the generator can be calculated.

Conclusion

Temperature of locomotive electric apparatus is more than a question for academic consideration; it is an active economic factor, never at rest and continually exerting its influence with time on the life of the equipment. The penalties of rash application or abusive operation are inescapable.

The effect of elevated temperatures on organic insulation materials follows the approximate rule of half the life for each 8–12-degree-centigrade increase in temperature.[3] The indisputable and direct approach to correct utilization or application of motive power is with a full knowledge of electric-apparatus temperature. The testing facilities and method outlined provide these necessary data for railroad operating and motive-power departments, as well as engineering information of application and design value. It is a means whereby a railroad can take the measure of its tough spots and with which the engineer can correct his shots.

References

1. American Standard *C* 35.1, Rotating Electrical Machinery on Railway Locomotives and Rail Cars and Trolley, Gasoline-Electric, and Oil-Electric Coaches, AIEE Standard 11, March 1943. Sections 156, 158–9.

2. Report on General Principles for Rating of Electrical Apparatus for Short-Time, Intermittent, or Varying Duty, AIEE Standard 1*A*, September 1941.

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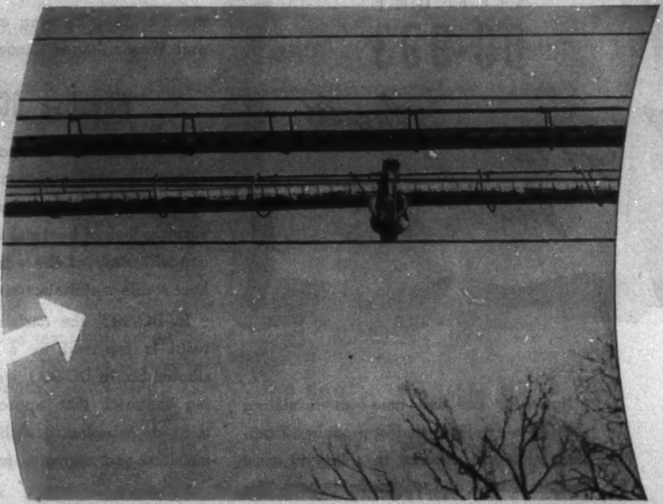

WHETHER PULLED INTO RINGS IN THE FIELD

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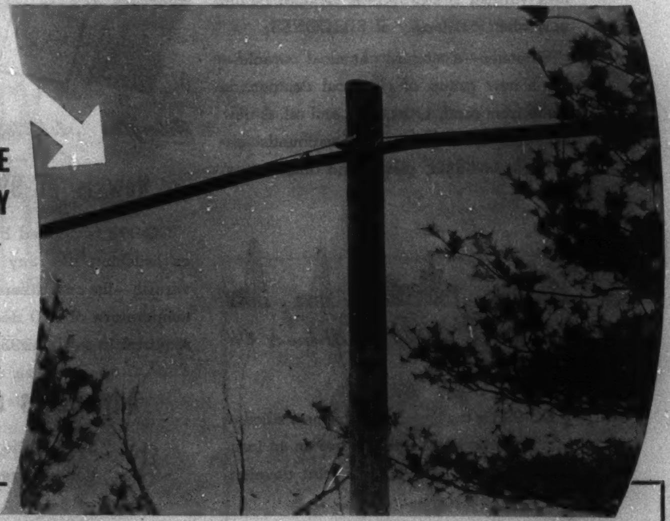
INCORPORATED WITH THE MESSENGER WIRE AT THE FACTORY



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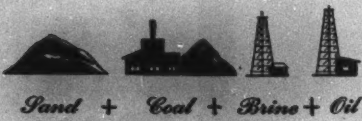
DC-993

A new value in Insulation

Now—for the first time—an insulating varnish is available that approaches Fiberglas, mica and asbestos in ability to resist heat, moisture and corrosive fumes. This new varnish is DC-993—a member of the new chemical family of SILICONES.

Silicones—a modern chemical miracle—are a new group of chemical compounds made from sand, brine, coal and oil. A new semi-inorganic group of compounds obtainable in liquid, plastic and other forms.

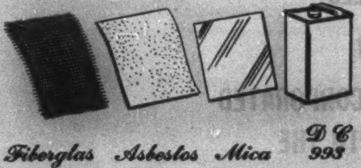


DC-993 is the member of this new silicone group that is best suited for use as an insulating varnish. DC-993 is a joint development of Dow Corning chemical research and Westinghouse "know-how".

Why Use DC-993?

The vulnerable component in ordinary varnish is organic carbon. When Fiberglas, asbestos or mica is bonded with an organic varnish, lack of heat stability in the varnish cancels many of the advantages of these heat stable materials.

In DC-993, the carbon skeleton of the resin is replaced by a chemically inert silicon. So, in DC-993, we have an insulating material that approaches Fiberglas, mica or asbestos in ability to resist heat, moisture and corrosive fumes.



How is DC-993 Applied?

DC-993 is applied by dipping, spraying or brushing like any ordinary insulating varnish—the only difference being, a baking temperature of 250 deg C (482 deg F) is required to set DC-993.

Advantages of DC-993

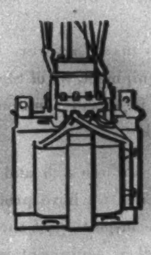
1 Service life of electrical insulation is increased many times.

2 Greater protection against excessive ambient temperatures and overload temperatures than is possible with conventional insulating varnishes.

3 Greatly increased protection from moisture and chemical laden atmospheres . . . because DC-993 is inert and does not become cracked or crazed after long service.

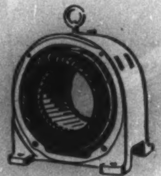
Proof—The improved insulating values of DC-993 have been proved both in laboratory tests and in service.

For instance—In one laboratory test, magnet coils insulated with DC-993 have been in operation over 10,000 hours at an observed temperature of 275 deg C (552 deg F).



For instance—A large number of magnet coils of various types insulated with DC-993 are in operation on street railway controls and records indicate a life considerably longer than Class B insulated coils.

For instance—A generator insulated with DC-993 ran 3000 hours at a temperature of 250 deg C (482 deg F), equal to a tremendously longer life at a normal operating temperature than obtainable with any other insulating varnish.



DC-993 is Available Now

DC-993 insulating varnish is available for immediate shipment in one, five, ten and fifty-gallon containers—also Fiberglas or asbestos insulating cloth, tape, tying cord and sleeving coated with DC-993; and Fiberglas and mica combinations can be supplied.

Write for descriptive booklet on DC-993. Write to Westinghouse Electric & Mfg. Company, P.O. Box 868, Pittsburgh 30, Pa.

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  - Monitors for television signals
- ELECTRICAL LABORATORY PRECISION MEASUREMENTS
  - Oscilloscopes
  - Comparison of Wave Shapes
  - Frequency Response
  - Power Distortions
- MEDICAL
  - Electrocardiograph
  - Reaction of nerve stimuli
- MECHANICAL
  - Measurement and visual indication of Tension
  - Stress analysis
  - Compression of engines
  - Vibrations
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  - Regulation of spring movements
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  - Musical tones study
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The part that the cathode-ray tube is destined to play in the industrial picture of tomorrow is dramatically suggested in its wartime applications.

The term "picture" is used advisedly. For the performance of the cathode-ray tube is pictorial. Thanks to its magical powers, hidden secrets are made to materialize . . . elusive phenomena are captured and crystallized so that they may be viewed and studied.

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As manufacturers of electronic testing equipment, we of Sherron Electronics have a first-hand familiarity with cathode-ray tubes.

In our research and development departments, we have produced equipment for the inspection of the cathode-ray tube, as well as equipment in which the cathode-ray tube has served as a measuring device.

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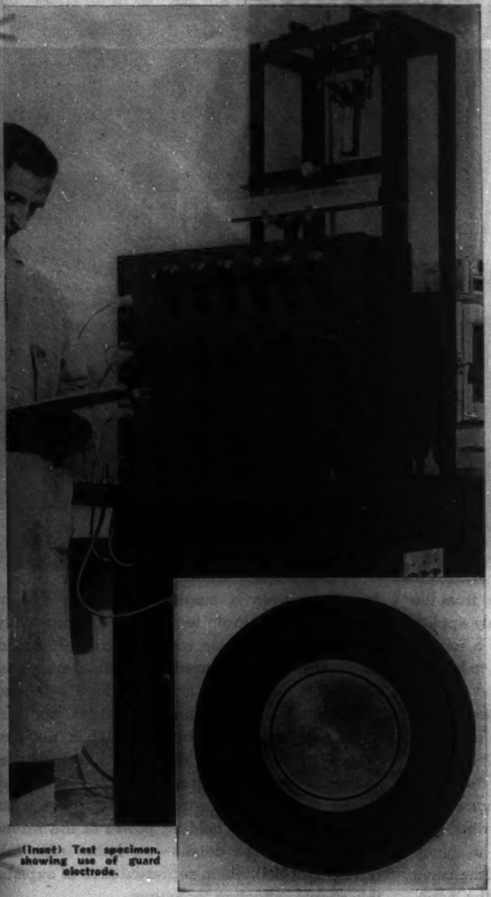

(Inset) Test specimen, showing use of guard electrode.

DOLPH Research and Testing Facilities Include Equipment to Determine Power Factor and Dielectric Constant of Insulating Varnish.

Data on dielectric constant and power factor of insulating varnish and insulating materials has long been of importance in the electrical field. Realizing this, the JOHN C. DOLPH COMPANY installed a Leeds and Northrup high voltage modified Schering Bridge. This measuring equipment is noted for its high degree of precision and is designed primarily for use on frequency of sixty cycles. The power factor of the specimen is read directly at this frequency on most materials. Operation can be effected up to a maximum voltage of 10 K.V.

Determination of dielectric constant and power factor is obtained while the specimen is under a voltage stress, thereby simulating actual operating conditions. This data is obtained with the highest possible degree of accuracy by the use of guard electrodes. (See Illustration.)

TWO PURPOSES SERVED

Production Check Any variations in quality due to improper processing of the varnish or variations in the raw materials used in formulations, can usually be detected through dielectric measurements.

Further Research Today, electrical manufacturers are seeking pertinent information on the electrical characteristics of insulating varnish films. We, of the JOHN C. DOLPH COMPANY, are now in a position to handle requests of this nature and we make this service available to you without any obligation on your part. Send us your inquiries and we will be glad to furnish you with the desired information.

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That's a phrase we're borrowing from the "Help Wanted" columns, for it certainly applies to Bethlehem's new serving tool . . . a tool so easy to use that any lineman can learn to handle it in a few minutes' time.

As the illustration shows, the device makes possible a neat, tremendously strong serve by means of the dead-end coil method. Using a 10-foot coil of 11-gage bethanized dead-end wire, the lineman hooks one end in place on the strand; then, engaging the wire between the fingers of the serving tool, he wraps it solidly in place with a simple rotary motion. Exhaustive tests have proved conclusively that the serve holds beyond the useful strength of the strand.

After a little practice, the lineman can make his serve in about the time required to attach conventional clamps. Besides, this serve is considerably more economical than the clamp method, for a coil of the necessary wire costs less than even a single inexpensive clamp.

The serving-tool technique is especially recommended for use with *bethanized* strand and wire—manufactured by Bethlehem Steel Company. One reason is that the highly ductile, uniform bethanized coating (almost 100 per cent pure zinc, applied electrolytically) is not displaced to any harmful extent by the operation of the serving tool. Moreover, when bethanized strand and dead-end wire are used, there is no question about the holding power of the serve.

Write for more details—or, better still, ask the nearest Bethlehem representative to explain this simple, effective technique.

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Industrial Multi-breakers are available in capacities from 15 to 100 amperes, with 2 or 3 poles. Quick make, quick break with dust-resisting sheet steel enclosures; also, explosion-resisting types. Front operated with trip indication.

Weatherproof, Dust-tight and Explosion-Resisting Circuit Breakers are furnished in cast iron enclosures with gray enamel finish. Standard conduit openings in the ends. Capacities—15 to 600 amperes up to 575 Volts.

Multi-breaker Type M Load Centers with 50 ampere frame breakers for applications involving 120-240 volt AC circuits. Available with varied number of single and double pole breakers of 15-20-25-35 and 50 ampere ratings. 100 ampere bussed mains available if required. Choice of surface or flush mounting devices for indoor installations and raintight boxes for outdoor applications.

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Industrial Circuit Breakers in standard sheet steel enclosures are available in capacities from 15 amperes to 600 amperes, up to 575 Volts. Made in 2 and 3 poles and for 3 and 4-wire systems. These devices are quick make and quick break with trip indication.

Multi-breaker Load Centers for controlling and protecting lighting and small power circuits. Made in a variety of circuit arrangements with capacities of 15, 20, 25, 35 and 50 amperes, for either 2 or 3-wire service, with individual trip.

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• **Square D Circuit Breakers** provide quick restoration of service after short circuit or overloads. They eliminate fuses and reduce maintenance cost since no replacement of parts is necessary. • Built into every Square D circuit breaker is a time-lag feature which permits harmless momentary overloads to pass without causing the unit to disconnect the circuit. • Square D's line of circuit breakers is unusually complete, assuring the right unit for any given installation. • See our catalog in Sweet's or write for Industrial Circuit Breaker Bulletin. Address Square D Company, 6060 Rivard Street, Detroit 11, Michigan.

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Vacuum tubes are an old story for Bell Laboratories scientists. Back in 1912 they made the first effective high vacuum tube. Three years later, they demonstrated the practical possibilities of tubes by making the first radio talk across the Atlantic, pointing the way to radio broadcasting. Since then, they have developed and utilized the vacuum tube wherever it promises better telephone communication — there are more than a million in your Bell Telephone System.

Today, Bell Telephone Laboratories is solving many of the toughest tube problems faced by the Armed Forces. When the war is over, it goes back to its regular job—keeping American telephone service the best in the world.

• This electrical replica of a heater-type pentode was made for use in German telephone repeaters.

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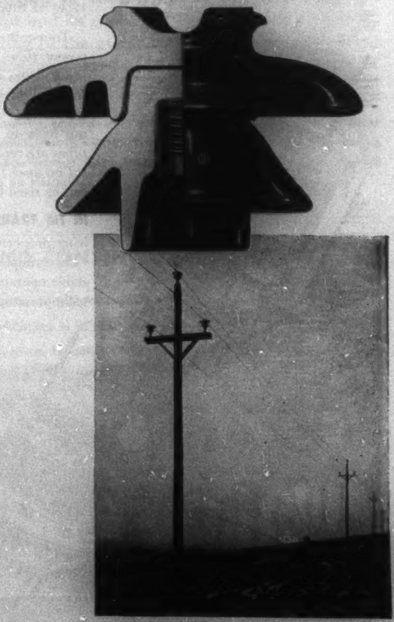

For dependability, compactness, simplicity, economy—consider RCA Beam-Power Tubes when designing transmitters

Beam-power tubes provide simple, compact equipment—a wide range of power-output—high power-sensitivity—over-all efficiency and economy.

IN AM TRANSMITTERS: Beam-power transmitting tubes provide high output with low driving-power. They enable you to design more compact, simpler, more economical broadcast transmitters than other types of tubes.

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This up-to-the-minute starter is a *combination* of our reduced voltage impedance starter and oil immersed safety disconnect switch with Rowan Air-Seal Fuses and Seal-Off Compartment for line, motor and control leads. Combining these Rowan advancements into one single unit conserves installation space and costs. *Maximum Safety is provided by mechanically interlocking the operating mechanism of the Safety Disconnect Switch with the Oil Tank.*

Reduced starting voltage is obtained by the use of continuous-wound coils with mechanical adjustment for varying the impressed voltage thereby eliminating tap failures.

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For safety, smooth acceleration, continuity of service and low overall cost—This ROWAN Type 900-KBF Combination Reduced Voltage Starter "Tops them all." Complete detailed information sent on request.

ADDED FEATURES THAT CONTRIBUTE TO SAFETY, LOW INSTALLATION COSTS AND CONTINUITY OF SERVICE

1. **Safety disconnect switch is completely interlocked with the oil tank in raised or lowered position—positive line disconnection.**
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3. **Rowan Air-Seal Fuses—A proven short circuit protection.**
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7. **Seal-off Terminal Compartment arranged for top and bottom conduit connections.**

More than a generation devoted to the design and manufacture of Oil Immersed AC Motor Controls.

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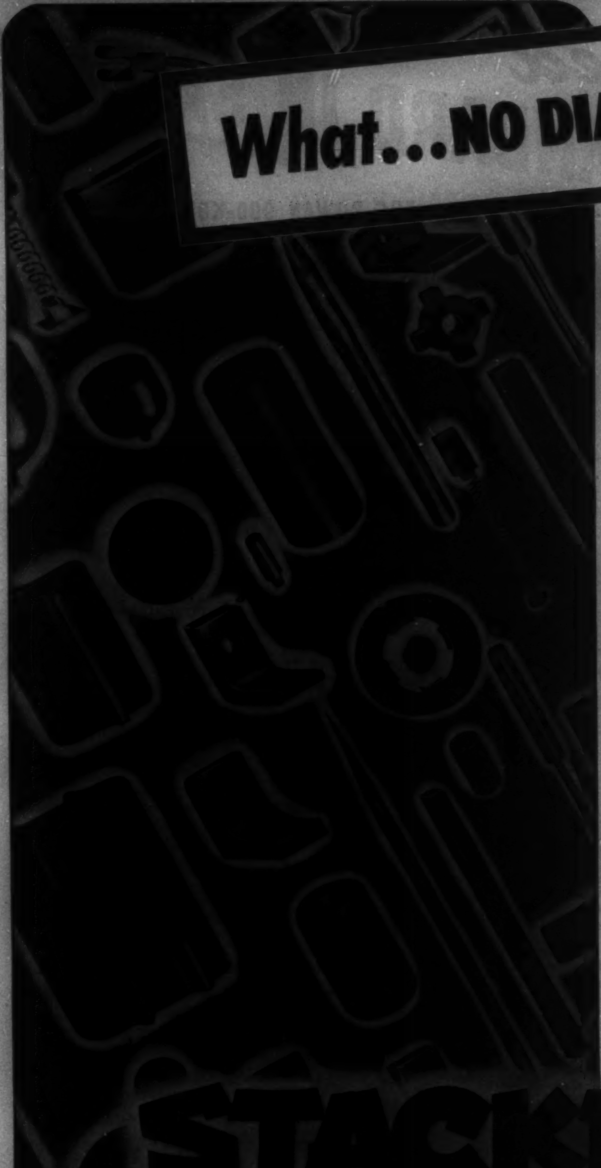

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Yes . . . no diamonds—but you can rely on Stackpole for just about everything else you need in the way of molded carbons, as well as graphites, metals, and compositions. The following give some idea of the extent of the Stackpole line:

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For all applications requiring an effective seal between a rotating and a stationary part

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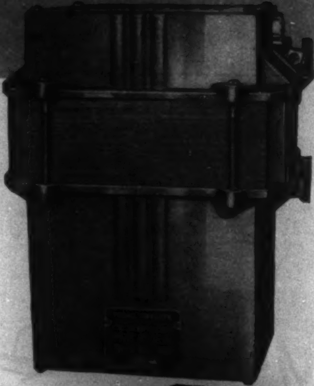
Keep Varying Input Voltages Uniform at ±½% of 1%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Built into new equipment or incorporated into equipment already in use, Raytheon Voltage Stabilizers improve the operation of electrical equipment by stabilizing varying input voltages to ±½% of 1% within 2 cycles.

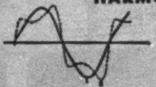
Because they have no moving parts . . . nothing that wears out, they require no adjustments or maintenance. Simply hook them up and Raytheon Voltage Stabilizers will give years of trouble-free service.

Many models and ratings are available for practically every application requiring uniform voltage. All stabilize voltages at any load within ratings to ±½%.

Standard Raytheon Voltage Stabilizers may be had for controlling A. C. input variation of 95 to 130 volts or 190 to 260 volts. Write for bulletin DL48-537. It gives dimensions, operating characteristics and other important data.

CASED MODEL

HARMONIC CONTENT



The high magnetic density in one of the transformers introduces harmonics in the output voltage wave. The actual harmonic content is usually unimportant except when instruments are being calibrated.

The output wave form is illustrated in the accompanying figure and table.

ANALYSIS OF OUTPUT VOLTAGE

Curve No.	Input Volts	Percentage Harmonic 1st	3rd	5th	7th
I	95	99.4	7.1	2.2	Trace
II	131	96.8	24.0	7.0	3.6

UNCASED MODEL

une in the Raytheon radio program: "MEET YOUR NAVY," every Saturday night on the Blue Network. Consult your local newspaper for time and station

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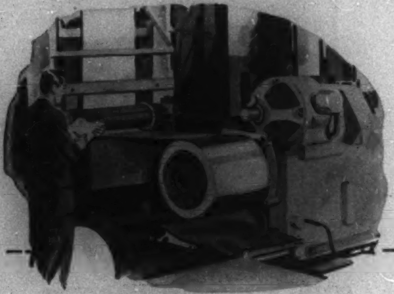
The coveted Army-Navy "E," for Excellence in the manufacture of war equipment and tubes, flies over all four Raytheon Plants where over 16,000 men and women are producing for VICTORY.

Devoted to research and manufacture of complete electronic equipment: receiving, transmitting and hearing aid tubes; transformers; and voltage stabilizers.

In an Army tank a GUNNER fires with deadly accuracy – while charging across rough terrain – because of a gun stabilizer, officially recognized as one *outstanding advantage* of our tanks over those of the enemy.

... the name on the GUN STABILIZER is Westinghouse.

TANK MOVES FORWARD
AT FULL SPEED
CANNON ST
ON TARG
DIRECT HIT

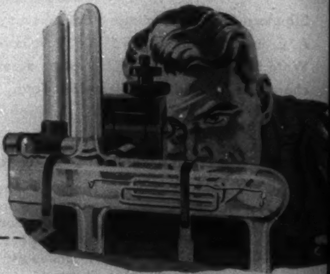


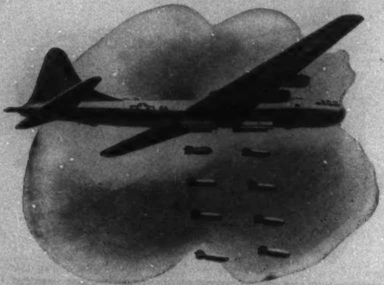
In a steel mill an ENGINEER uses an induction heater to fuse a mirror-like surface on dull electrolytic tin plate – helping to conserve *two-thirds* of our war-scarce tin supply.

... the name on the INDUCTION HEATER is Westinghouse.

In a laboratory a SCIENTIST uses a microbalance to weigh a *single layer of oxygen atoms,* 1/50,000,000th ounce, to determine the corrosion resistance of special alloys at high temperatures.

... the name on the MICRO-BALANCE is Westinghouse.





In a bomber a BOMBARDIER "pin-points" his target with an American bombsight – controlled by a gyroscope which is driven by an electric motor, balanced to *1/10,000th ounce*

... the name on the ELECTRIC MOTOR is Westinghouse.

TODAY – Westinghouse is producing vital war equipmen and weapons, many of which must remain secret unti after final Victory.

TOMORROW – These wartime developments will b turned to peaceful uses – products for industry and th home, backed by Westinghouse research, engineering, an precision manufacture.

Westinghouse
PLANTS IN 25 CITIES OFFICES EVERYWHERE

Tune in: JOHN CHARLES THOMAS–Sunday 2:30 pm, EWT, NBC • TED MALONE–Mon. thru Fri., 11:45 am, EWT, Blue Networ

TIREX
SELENIUM
Rubber Armor

UNDERNEATH Old Man River

THESE pictures illustrate the laying of a 3-conductor # 4/0 rubber insulated submarine power cable built recently for one of the Southern power companies. The cable is being laid on the bottom of the Mississippi River. It will be used to supply power to the war industries located on the opposite bank of the Father of Waters.

It was natural for the power company in question to turn to Simplex to help engineer and manufacture this cable, because Simplex tailor-made cables are known far and wide for their dependability and long service life.

It is these intrinsic qualities in all Simplex cables that make them so desirable. When you need help in designing power cables rely on the Simplex Engineering Department. Their wide experience is at your service and there is no obligation.

Simplex Wire & Cable Co., 79 Sidney Street, Cambridge 39, Mass.

Simplex
WIRES and CABLES

HOW EXCELLENCE IS BUILT INT

Sangamo
MICA
CAPACITORS

• Vacuum impregnation tank and waxing equipment for special treatment of mica films.

SANGAMO ELECTRI

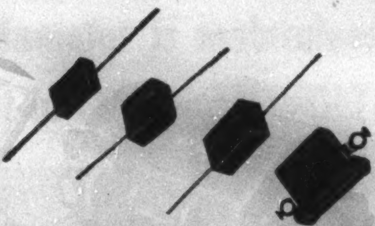
[illegible]

Cartridge MPREGNATION

THE processing of the capacitor car-idge before moulding is a very im-ortant step in controlling the quality the finished capacitor. Not only ust all traces of air and moisture be moved from the cartridge, but the rtridge must also be treated to in-re permanence of the desired char-cteristics, such as power factor and sulation resistance, when once these ave been attained.

These conditions are achieved by bjecting the cartridges to a high de-ree of vacuum for the removal of oisture and air, and by impregnating hem with moisture resistant waxes or rnishes, in special vacuum impreg-ating tanks. To assure that the pre-ribed electrical characteristics are btained, various waxes and varnishes ay be used. All excess wax is removed y centrifugal force so that it does not terfere with the proper moulding of e plastic case in the subsequent oper-ion. The plastic case additionally als the capacitor against atmospheric nditions, thus further contributing the long, trouble-free life of capaci-rs in service.

By maintaining constant vigilance each of the manufacturing proces-s, the Sangamo standard of excel-nce is assured for Sangamo Mica apacitors.



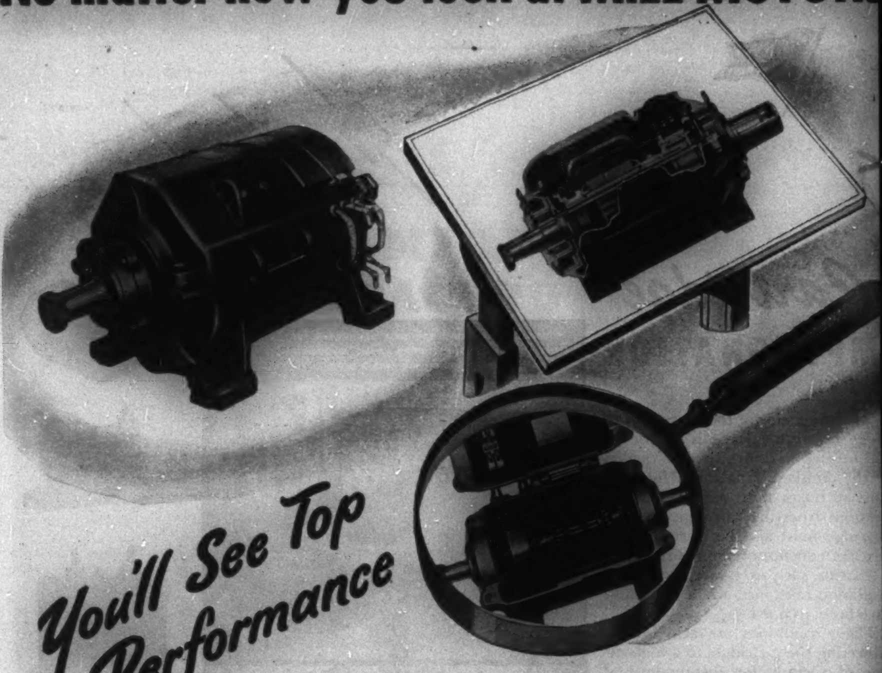
• Impregnating and spinning equipment for vacuum wax impregnating mica capacitor cartridges and spinning off excess wax.

• Impregnating tank for vacuum impregnation of capacitors and capacitor cartridges.

COMPANY SPRINGFIELD ILLINOIS

[illegible] TIME SWITCHES

No matter how you look at MILL MOTORS



You'll See Top Performance with AX5's or SA35's

Go into any steel mill today. You'll see excellent mill motors like these . . . giving unprecedented round-the-clock service!

In more and more of such heavy-duty motors, "National" Grade AX5 or Grade SA35 brushes are being installed. Operating men have learned that both of these electro-graphitic brush grades are *strong mechanically* . . . have superior commutating characteristics . . . combine high contact drop with low coefficient of friction . . . and are non-abrasive!

Both grades were developed after thoroug studies of load and atmospheric conditions, com mutator maintenance problems and many othe practical, steel-mill operating factors.

They are but two of a number of carbon graphite, electro-graphitic and metal-graphit brush grades that National Carbon Company, Inc. has developed to meet the varying needs of ever class of rotating electrical equipment . . . from frac tional horsepower motors to the largest motor and generators

The word "National" is a registered trade-mark of National Carbon Company, Inc.

NATIONAL CARBON COMPANY, INC.

Unit of Union Carbide and Carbon Corporation

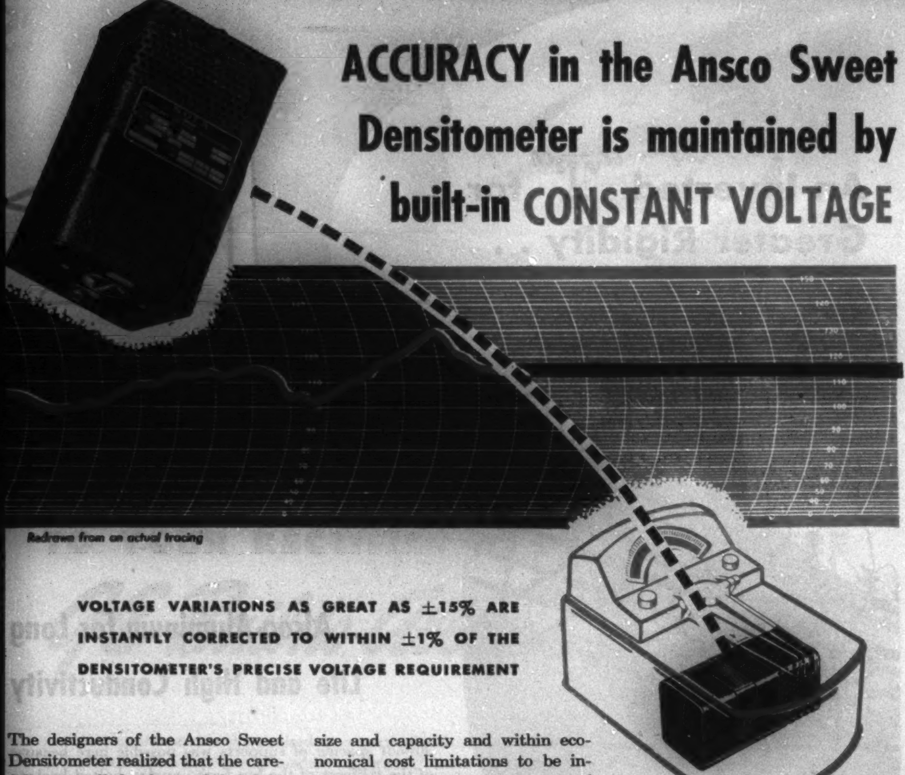
UCC

General Offices: 30 East 42nd Street, New York 17, N. Y.

Division Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

KEEP YOUR EYE ON THE INFANTRY . . . THE DOUGHBOY DOES I

ACCURACY in the Ansco Sweet Densitometer is maintained by built-in CONSTANT VOLTAGE


Redrawn from an actual tracing

VOLTAGE VARIATIONS AS GREAT AS ±15% ARE INSTANTLY CORRECTED TO WITHIN ±1% OF THE DENSITOMETER'S PRECISE VOLTAGE REQUIREMENT

The designers of the Ansco Sweet Densitometer realized that the carefully controlled voltage of their laboratory would never be consistently available to their instruments in the field. Yet the operating voltage must be maintained within an allowable tolerance of ±1% of rated requirements if instant and accurate answers were to be obtained in the study of the sensitometric problems for which it was designed.

In consultation with Sola engineers a Sola Constant Voltage Transformer was designed in correct size and capacity and within economical cost limitations to be incorporated as a component part of the equipment. Laboratory voltage goes with the instruments into the field.

The same problem confronts *all* designers of electronic instruments or electrically operated equipment. And the same practical solution so successfully employed in the Ansco Sweet Densitometer and many other similar instruments and devices is available—a Sola Constant Voltage Transformer as a built-in component.

For the operation of precision instruments and equipment already in use, Sola Constant Voltage Transformers are available in standard units in capacities from 10Va to 15KVA. Special units can be economically designed for any built-in application. Consultation *now* with Sola engineers will provide a satisfactory solution for your problem.

SOLA Constant Voltage Transformers

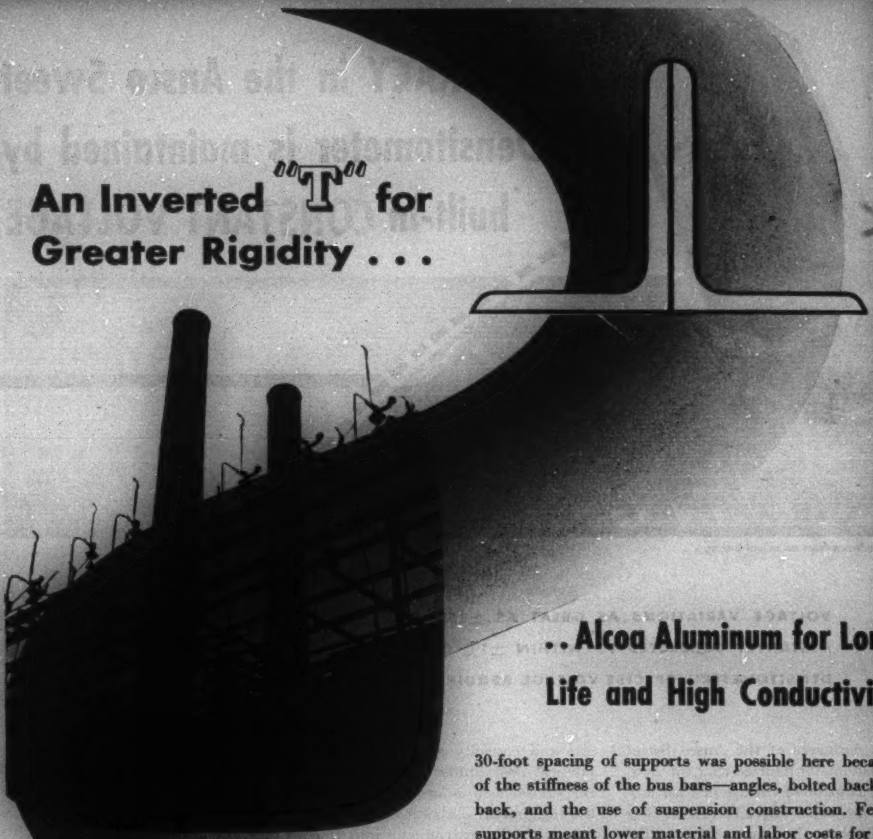
To Manufacturers:

Built-in voltage control guarantees the voltage called for on your label. Consult our engineers on details of design specifications.

Ask for Bulletin ACV-102

Transformers for: Constant Voltage • Cold Cathode Lighting • Mercury Lamps • Series Lighting • Fluorescent Lighting • X-Ray Equipment • Luminous Tube Signs
Oil Burner Ignition • Radio • Power • Controls • Signal Systems • Door Bells and Chimes • etc. **SOLA ELECTRIC CO., 2525 Clybourn Ave., Chicago 14, Ill.**

An Inverted "T" for Greater Rigidity . . .



[illegible] Alcoa Aluminum bus bars [illegible] the Mahoning Substation [illegible] Ohio Public Service Company, Warren, Ohio.

. . Alcoa Aluminum for Long Life and High Conductivity

30-foot spacing of supports was possible here because of the stiffness of the bus bars—angles, bolted back to back, and the use of suspension construction. Fewer supports meant lower material and labor costs for the structure, fewer insulators to maintain.

Aluminum provides high electrical conductivity to take care of expanding power loads. Aluminum has the ability to withstand the attack of corrosive industrial atmospheres.

Alcoa Aluminum bus bars—rounds, flats, angles and channels— and fittings are available now for the expansion of old stations or the building of new. May we quote on your requirements? Write Aluminum Company of America, 2149 Gulf Building, Pittsburgh 19, Pennsylvania.

ALCOA ALUMINUM

THE CORRECT ANSWER
TO YOUR RECTIFIER PROBLEM IS HERE

G-E Builds All Three

Selecting the rectifier best suited for a particular d-c application is not a decision that can be made on a "guess" basis. Construction, basic materials, operating characteristics, weight, size, cost and life expectancy are all factors that should be considered.

G.E. and only G.E. builds the three types of low-voltage rectifiers most generally used—copper-oxide, selenium and Tungar. All three are tops in quality and leaders in their field. To say that one type is better than another is as fatuous as saying a bomber is better than a fighter plane. Each performs best when doing the job for which it was specifically designed.

When blueprints call for rectifiers choose the correct size and type from the G-E line. If you're not sure of what is best for your need let G-E engineers help you. Years of experience qualify them to recommend the rectifier which will give you the most economical, most efficient and most reliable performance. Whether they recommend copper-oxide, selenium or Tungar you can be sure their selection is impartial because G.E. offers all three.

For more information write to Section A-754-32, Appliance and Merchandise Dept., General Electric Co., Bridgeport, Conn.

Copper-oxide
Selenium
Tungar

Hear the General Electric radio programs: "The G-E All Girl Orchestra" Sunday 10 p.m. EWT, NBC. "The World Today" news every weekday 6:45 p.m. EWT, CBS. "The G-E House Party" Monday through Friday 4:00 p.m. EWT, CBS.

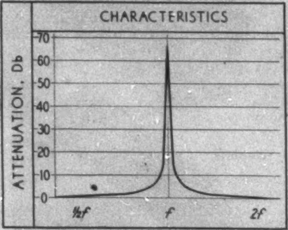
BUY WAR BONDS AND KEEP THEM

GENERAL ELECTRIC

LABORATORY INSTRUMENTS FOR SPEED AND ACCURACY

This instrument separates harmonics from a desired frequency

By eliminating the fundamental frequency, this instrument permits accurate measurement of noise, distortion and the harmonics of the wave. At balance its fundamental circuit has almost infinite attenuation at a single frequency and other frequencies are passed with little or no attenuation.



As shown in the chart: the attenuation at the 2nd harmonic (2F) would be in the order of 1/2 db while at the resonant frequency it would be infinite—from 60 to 70 db in practical circuits making it possible to measure distortions as low as 0.1%.

The *-hp-* Model 325B Noise and Distortion Analyzer is really a combination of three separate elements: a frequency elimination circuit, a stabilized 20 db amplifier and a vacuum tube voltmeter, any one of which may be used individually. The amplifier employs inverse feedback and is very stable . . . accuracy is independent of line voltage and tube characteristics. Because the input is to the grid of the amplifier and is equivalent to 200,000 ohms, it will not load down the circuit being measured. The sensitivity of the vacuum tube voltmeter in combination with the amplifier is such that hum may be measured directly and voltage measured as low as .0005.

The *-hp-* Model 325B covers the audio frequency spectrum, supplying frequencies of 30 cps, 50 cps, 100 cps, 400 cps, 1000 cps, 5000 cps, 7500 cps, 10,000 cps and 15,000 cps within ± 5%. These frequencies cover FCC recommendations for checking FM as well as AM broadcast. The meter scale is calibrated in volts and in dbs.

The *-hp-* Model 325B in combination with *-hp-* 200 series Audio Oscillators provides equipment to make most laboratory AF measurements including distortion, power, gain and frequency response. Write for complete information now.

HEWLETT-PACKARD COMPANY

BOX 1045B · STATION A · PALO ALTO, CALIFORNIA

Audio Frequency Oscillators · *Signal Generators* · *Vacuum Tube Voltmeters*
Noise and Distortion Analyzers · *Wave Analyzers* · *Frequency Meters*
Square Wave Generators · *Frequency Standards* · *Attenuators* · *Electronic Tachometers*

OTHER -*hp*- INSTRUMENTS

Distortion Analyzer

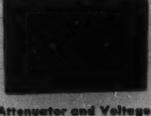
The Model 320A consists of two fundamental elimination circuits, 400 cps and 5000 cps, together with a calibrated attenuator reading in decibels.

Distortion Analyzer

The Model 320B consists of six fundamental elimination circuits, 50, 100, 400, 1000, 5000 and 7500 cps, together with a calibrated attenuator reading in decibels.

Harmonic Wave Analyzer

The Model 300A consists of a highly selective amplifier which measures the individual components of a complex wave.



Attenuator and Voltage Divider

The Model 350A is a bridged-T attenuator consisting of one 100 db attenuator with 10 db steps and a 10 db attenuator having 1 db steps.

IT'S THE MATING SEASON FOR GLASS AND METAL . . .

thanks to Corning Metallizing!

CORNING has long been interested in the mating qualities of glass and metal. Out of this interest as developed a metallizing process which can be accurately *controlled* . . . and which lasts.

Corning's metallizing process, combined with the xcellent mechanical and dielectric properties of Corning's glasses, produces hermetic seals between lass components and metal by ordinary soldering methods or furnishes accurate and constant capacitances and inductances or electrostatic shielding.

Metallized glass as developed by Corning offers a wide variety of new applications in the field of electronics. Perhaps you have a problem where the union of glass and metal can help. Why not write us about it? Address Electronic Sales Department, N-7, Bulb and Tubing Division, Corning Glass Works, Corning, New York.

CORNING
means
Research in Glass

Electronic Glassware

VYCOR
CORNING
PYREX

"PYREX", "VYCOR" and "CORNING" are registered trade-marks and indicate manufacture by Corning Glass Works, Corning, N. Y.

moisture excluded

DOW CORNING
SILICONES
TRADE MARK

Dow Corning No. 4 Ignition Sealing Compound

In the heat of battle over miring terrain, the disconnect junctions of ignition and radar units are perfectly protected against failure by this *all-silicone* sealing compound. This same protection is provided to electrical equipment under the most humid plant conditions. Dow Corning No. 4 has the consistency of a soft grease, and neither melts nor hardens over the temperature range of —40°F. to 400°F.

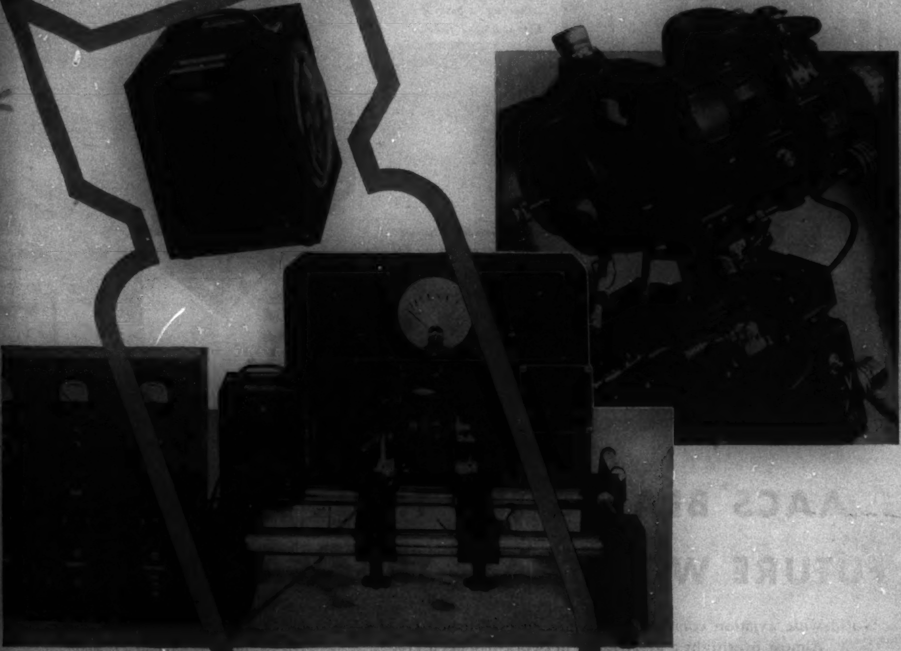
Here is the assurance of uninterrupted performance —in a sealing compound having excellent dielectric properties . . . one that provides positive exclusion of moisture, permanent lubrication for insulated conductors, protection against vulcanization caused by overheating.

Dow Corning No. 4 is in commercial production—one of a growing family of silicone products essential to the more successful, more economical functioning of electrical and other industrial and technical equipment.

DOW CORNING CORPORATION
MIDLAND, MICHIGAN
ADDRESS ALL INQUIRIES TO BOX 592

Dow Corning
FIRST IN SILICONES

PRECISION *to 0.000070 Inch!*



● One of the mechanical marvels of the war is the famed Norden Bombsight, until recently one of the most secret of military devices. Information on some of its general features has now been released by the Army.

This bombsight is probably the most precise instrument in the world, yet it is being built in mass production by the Victor Adding Machine Company and several other manufacturers.

The heart of the bombsight and its associated stabilizer are two gyros which have to be balanced to almost unheard-of accuracy. When inspected, the rotor must be centered to *70 millionths of an inch.*

To obtain this accuracy, each gyro is carefully adjusted on the balancing machine shown in the illustration. This portable unit is manufactured by the Gisholt Machine Company. General Radio's STROBOTAC is a part of this machine.

The control equipment at the left includes an electronic speed regulator which maintains the gyro at the speed selected by the STROBOTAC. The equipment behind the gyro measures the amount of weight to be removed from the gyro rotor to give balance, while the STROBOTAC again is used to point out the angular position at which unbalance should be removed.

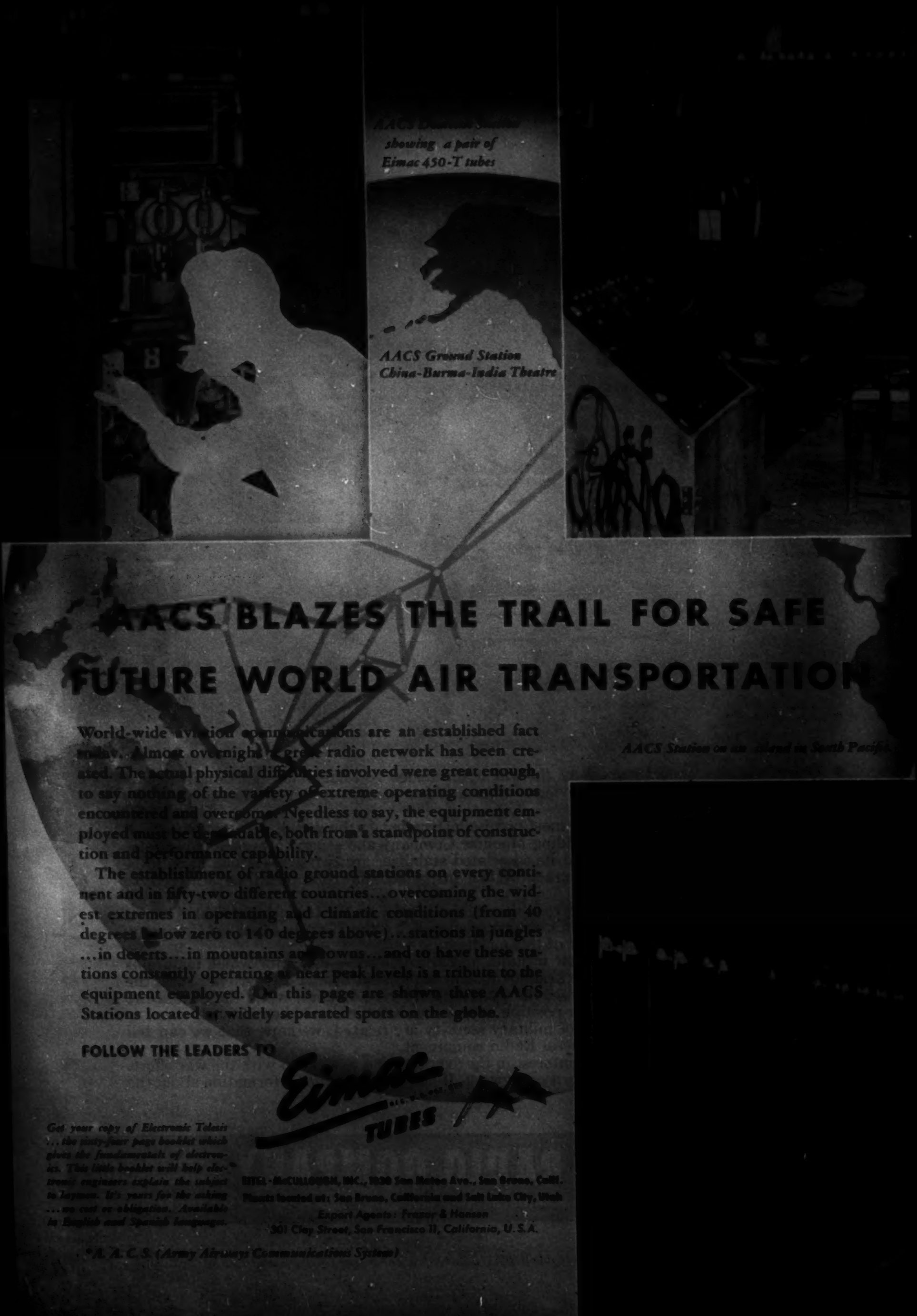
Gradually as the requirements of military security are relaxed, we hope that we can tell you of many other war uses for General Radio equipment.

In the meantime, possibly your interest in the STROBOTAC is associated with the war effort. STROBOTACS are available for top-priority war work. If you'd like detailed information about the STROBOTAC, ask for Bulletin 963

GENERAL RADIO COMPANY

Cambridge 39,
Massachusetts

90 West St., New York 6 · 920 S. Michigan Ave., Chicago 5 · 1000 N. Seward St., Los Angeles 38



AACS [illegible] Station showing a pair of Eimac 450-T tubes

AACS Ground Station China-Burma-India Theatre

AACS Station on an Island in South Pacific

AACS BLAZES THE TRAIL FOR SAFE FUTURE WORLD AIR TRANSPORTATION

World-wide aviation communications are an established fact today. Almost overnight a great radio network has been created. The actual physical difficulties involved were great enough, to say nothing of the variety of extreme operating conditions encountered and overcome. Needless to say, the equipment employed must be dependable, both from a standpoint of construction and performance capability.

The establishment of radio ground stations on every continent and in fifty-two different countries…overcoming the widest extremes in operating and climatic conditions (from 40 degrees below zero to 140 degrees above)…stations in jungles …in deserts…in mountains and towns…and to have these stations constantly operating at near peak levels is a tribute to the equipment employed. On this page are shown three AACS Stations located at widely separated spots on the globe.

FOLLOW THE LEADERS TO

Get your copy of Electronic Telesis …the sixty-four page booklet which gives the fundamentals of electronics. This little booklet will help electronic engineers explain the subject to laymen. It's yours for the asking …no cost or obligation. Available in English and Spanish languages.

EITEL-McCULLOUGH, INC., 1030 San Mateo Ave., San Bruno, Calif.
Plants located at: San Bruno, California and Salt Lake City, Utah
Export Agents: Frazar & Hansen
301 Clay Street, San Francisco 11, California, U.S.A.

**A. A. C. S. (Army Airways Communications System)*

The most revolutionary advance in modern oil-hydraulics

MULTIPRESS with VIBRATORY HydrOILic PRESSURE

FAST APPROACH PORTION OF STROKE (FIXED SPEED)
REGULATIVE PRESSING SPEED PORTION OF STROKE (20 to 200 ipm)
MANUAL OR FULLY AUTOMATIC RAM CYCLING
EACH REPEAT STROKE EXERTS EXACT PRE-SET PRESSURE
DENISON HydrOILic MULTIPRESS
LENGTH OF REPEAT STROKES REGULATIVE .004 to ½ inch
NUMBER OF REPEAT STROKES REGULATIVE 1 to 25, automatically 1 to infinity, manually
FREQUENCY OF REPEAT STROKES REGULATIVE
RAM FOLLOWS WORK AS IT YIELDS, EXERTING EXACT PRESSURE

MULTI
Basic Unit
$575.00
Patents Applied For

Vibratory HydrOILic Pressure — just *one* of many unique control features available with the amazing new MULTIPRESS — imparts any pre-set number of short, rapidly-repeated, exact-pressure strokes *upon each full downstroke of the ram!*

As shown above, these repeat strokes are regulative in length, pressure, speed, frequency, and number per ram cycle. And the ram *follows the work* downward as it yields, exerting exact pre-set pressure on each vibratory stroke.

MULTIPRESS — a completely self-contained, motor-driven, oil-hydraulic bench press, in 4 and 6-ton sizes — makes this *exactly controlled* vibratory action available at surprisingly low cost. Other MULTIPRESS accessories include automatic cycling controls, straightening fixtures, reciprocating tables, pelleting devices, automatic indexing tables, foil feeds, a variety of bolster plates, benches, extension tables, side shelves — to mention only a few. Write today for further information. The Denison Engineering Co., 1192 Dublin Rd., Columbus 16, O.

DENISON EQUIPMENT *for* APPLIED HydrOILics

HydrOILics INDUSTRY'S RIGHT HAND

Foremost Manufacturers of Transformers to the ELECTRONIC INDUSTRY

UTC

UTC OUNCER TRANSFORMER
AVAILABLE HERMETICALLY SEALED

Should you have limited space requirements, this transformer (the smallest hermetically sealed unit now available) can be supplied to specifications.

ALL PLANTS

United Transformer Corp.

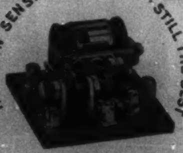
150 VARICK STREET NEW YORK 13, N. Y.

INSTANT
CURRENT MEASUREMENTS

Instantaneously, by merely "snapping" the tongs around any electrical circuit, you can measure the current—BOTH A.C. and D.C. up to 800 amperes—without necessitating a break in circuit or insulation. Every plant electrician should have one. It's a time saver—a production speeder. Weighs only 2¾ lbs. and is as simple to use as the illustration above suggests. Write today for our TONGTEST Bulletin describing its many time-saving applications.

COLUMBIA ELECTRIC MFG. CO.
4519 Hamilton Ave., N.E., Cleveland 14, Ohio

COLUMBIA TONG TEST AMMETERS



"KURMAN SENSITIVE" OF 1930 · STILL THE BEST

New Features added to KURMAN RELAYS

The Well-Known
KURMAN SENSITIVE RELAY

the first to demonstrate the superior magnetic properties of hydrogen-annealed nickel alloy 15 years ago—again introduces an outstanding new feature:—

CHATTERLESS OPERATION

— obtained through cushioning of contacts in an energy absorbing material. This feature enables keying up to 150 words p. m. Mica insulation of the armature makes the relay suitable for keying 50 m. c. RF signals.

25 YEARS' EXPERIENCE, a thoroughly competent staff of Development and Design Engineers, and complete manufacturing facilities are at your service when you submit your Relay problems to us.

For trouble-free operation in any climate and at any desired altitude,

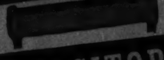
HERMETICALLY SEALED relays are available, either of plug-in type or equipped with solder lugs. Some of these relays take as little space as 2" x 1¼" dia., and have up to 10 amps current capacity due to the special atmosphere introduced into the container under pressure.

Write for details on:
KURMAN LINE OF RELAYS
KURMAN VIBRATOR CONVERTERS
KURMAN MICROPHONE HUMMERS

KURMAN ELECTRIC CO.
35-18 37th STREET • LONG ISLAND CITY 1, N. Y.

HI-Q

WIRE WOUND RESISTORS



CERAMIC CAPACITORS

CHOKE COILS

PERFORMANCE ENGINEERED

ELECTRICAL REACTANCE CORPORATION
FRANKLINVILLE, N. Y.

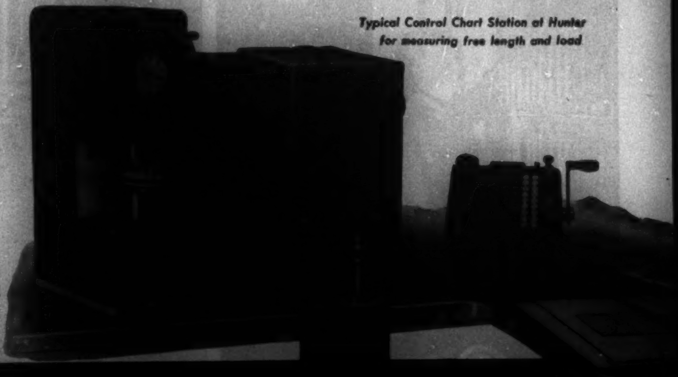
Flow Chart for Quality Control

Efficient control over the quality of precision springs requires active and intelligent application of statistical methods, using testing and measuring devices possessing accuracy and speed standards unheard of less than three years ago.

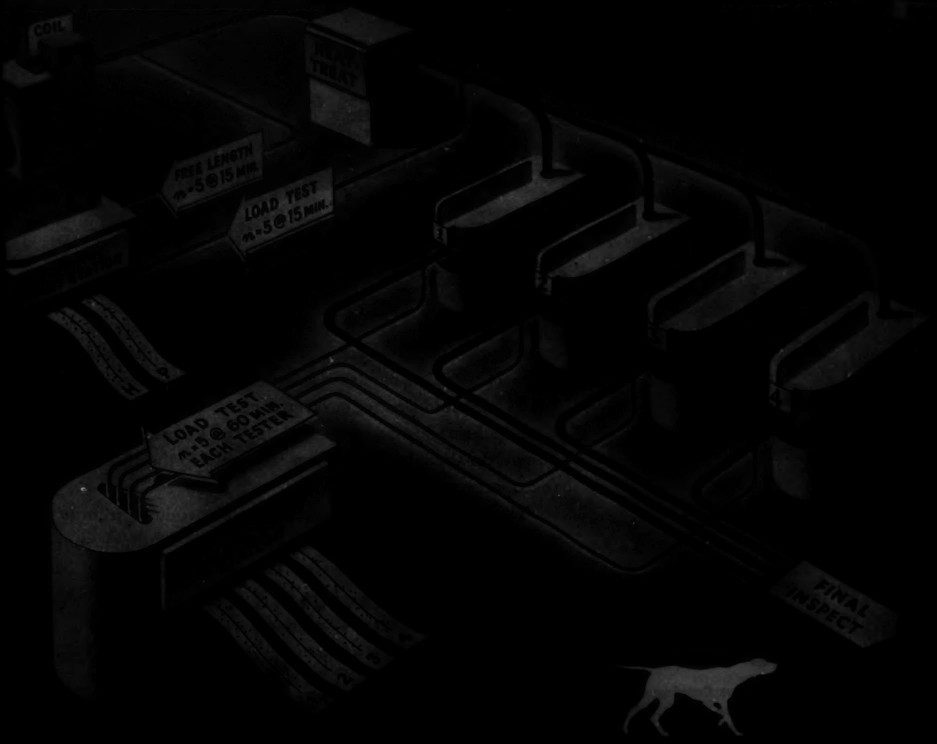
These new inspection techniques have been in full use at Hunter for some time.

The development and manufacture of our own new electronically-operated devices reached such proportions that we had to create a new "Special Apparatus" department to handle the work.

Below, you see how the quality function ties into the manufacturing cycle. The artist's drawing is based on an actual flow chart for close tolerance compression springs.



Typical Control Chart Station at Hunter for measuring free length and load


COIL
HEAT TREAT
FREE LENGTH
n=5 @ 15 MIN.
LOAD TEST
n=5 @ 15 MIN.
1
2
3
4
LOAD TEST
n=5 @ 60 MIN.
EACH TESTER
FINAL INSPECT

NTER PRESSED STEEL COMPANY, LANSDALE, PENNA

Springs, Metal Stampings, Wire Forms, Mechanical and Electrical Assemblies

OHMITE RHEOSTATS

In Production of Steel

ILLUSTRATED ABOVE is a six-ton top-charge electric arc furnace, for the manufacture of high quality special steels. Here the average arc current value *must* be held to minimum variation. For each phase of this three-phase arc furnace, there is a separate Regulex exciter motor-generator set to maintain proper current control. The current settings in each phase are made by the Ohmite Rheostats shown on the back of the control panel to the right of the operator.

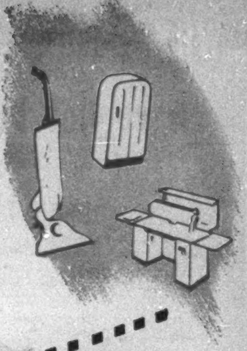
This is but one of the many critical production tools which depend on Ohmite Rheostats for smooth, close control. Many types and sizes for every need.

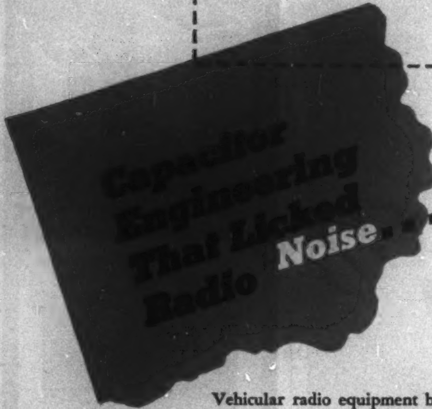
OHMITE MANUFACTURING COMPANY
4801 FLOURNOY STREET ★ CHICAGO 44, U. S. A.
Foremost Manufacturers of Rheostats, Resistors, Tap Switches

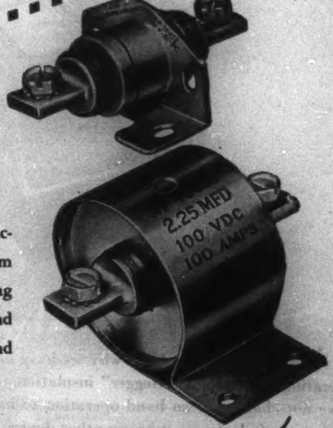
Send for Catalog and Engineering Manual No. 40
Write on company letterhead for this helpful guide in the selection and application of tap switches, rheostats, resistors. Address Ohmite Mfg. Co., 4801 Flournoy St., Chicago 44

Be Right with OHMITE
RHEOSTATS • RESISTORS • TAP SWITCHES

stop that **noise!**




Capacitor Engineering That Licked Radio Noise. . .



Vehicular radio equipment being manufactured now for military use is free from radio noise . . . thanks to the engineering that produced small compact capacitors and filters for generators, inverters, motors and other equipment.

The NF series of C-D feed-thru capacitors is specially designed and built for this service . . . to reduce radio noise.

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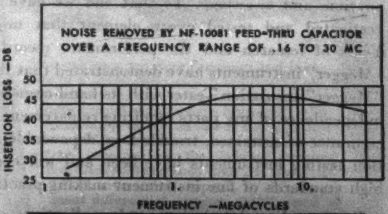
Other types of filters and feed thru capacitors are available in a range of sizes and ratings.

Write for information. Cornell-Dubilier Electric Corporation, South Plainfield, N. J. Other plants at New Bedford, Brookline, Worcester, Mass., and Providence, R. I.



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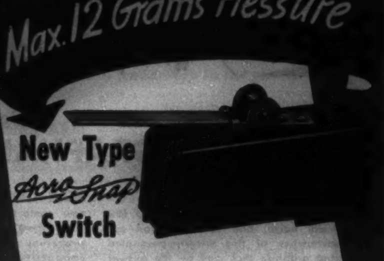

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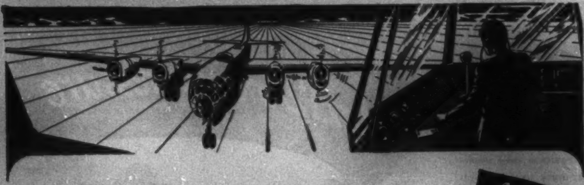

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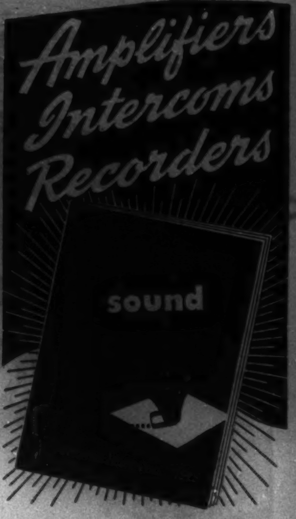

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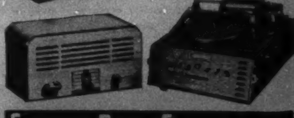

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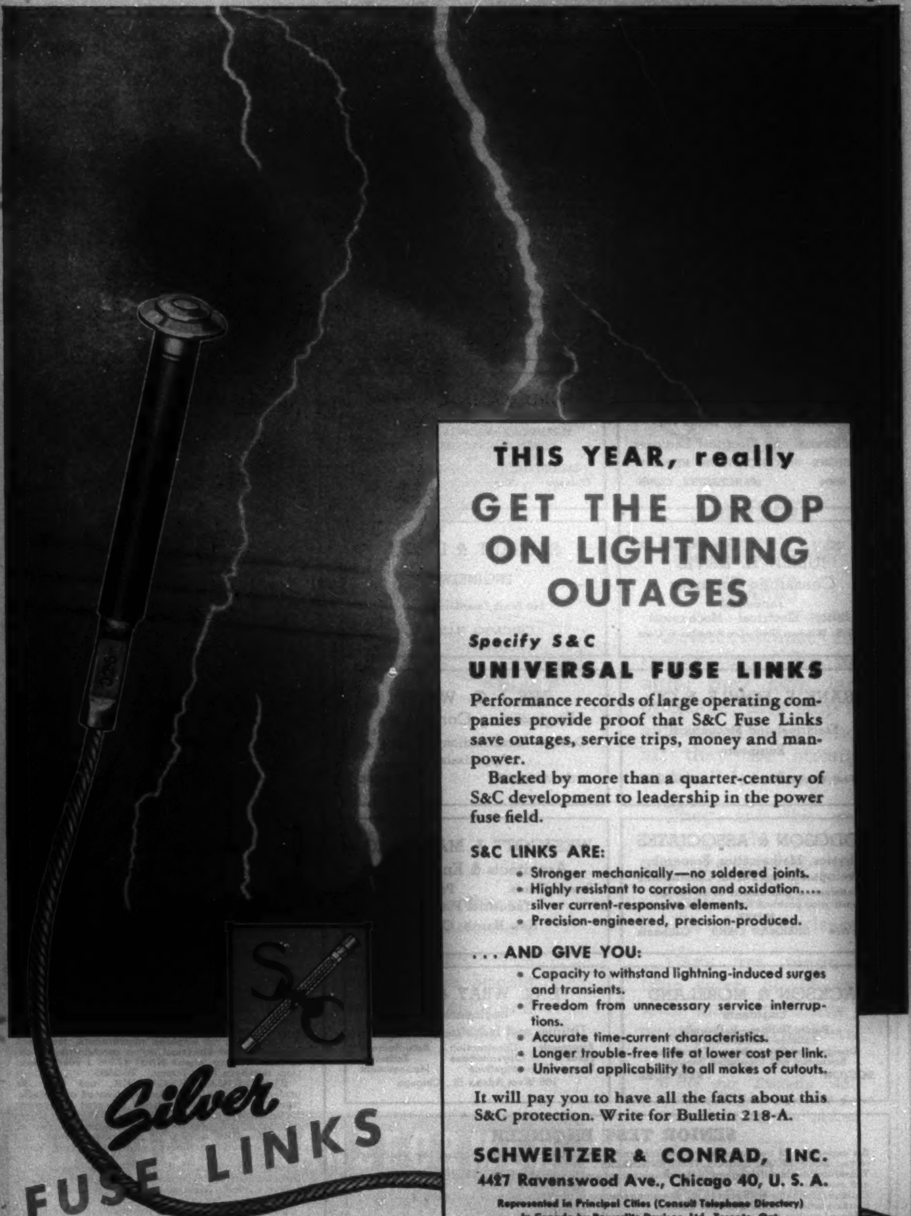

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ELEC-MECH ENGR; graduate; 20 yrs des, constr, and opern; 17 yrs in responsible charge. Exp covers heavy machinery, diesel-generation, substations up to 110 KV, pumping systems, etc; last 2 yrs Chief E.E. for large industrial. E-104.

ELEC ENGR; 46; graduate; family. Four yrs transformer des; 13 yrs constr, maintenence railway substations; 4 yrs des plant facilities; exper relay settings, short circuit calculations. Desires pos West Coast. E-105.

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GRAD ELEC ENGR; 34; 8 yrs exper pwr plant and industrial des, installation and maintenance. Desires permanent elec mech engg pos in industrial organization with opportunities for aggressive engr. Engaged, available. Western U. S. preferred. E-107.

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CHIEF ENGINEER AND A CHIEF ELECTRICIAN for a lead, zinc and silver mining operation. Salaries, to $4800 a year, depending upon experience. Location, Bolivia. W-5400.

FACTORY MANAGER to take charge of plant manufacturing electrolytic capacitors. Should have full engineering knowledge of electrolytics as well as the ability to manage people, plan equipment, supervise production, etc. Good opportunity. Salary open. Location, Massachusetts. W-5465-B.

SALES ENGINEERS for overseas trade, 25–31, graduate mechanical, chemical or electrical, with some business or sales experience, an understanding of the economics of international trade and some knowledge of foreign buying practices. Must be willing to travel anywhere. Must speak Spanish or French fluently. Excellent opportunity. Write stating past and present work and salary, draft status and attach photograph. W-5538.

ELECTRICAL ENGINEER, graduate, with several years' experience in industrial plants. Must be familiar with generators, motors and electrical equipment. Salary, $6000 a year. Permanent. Location, Massachusetts. W-5540.

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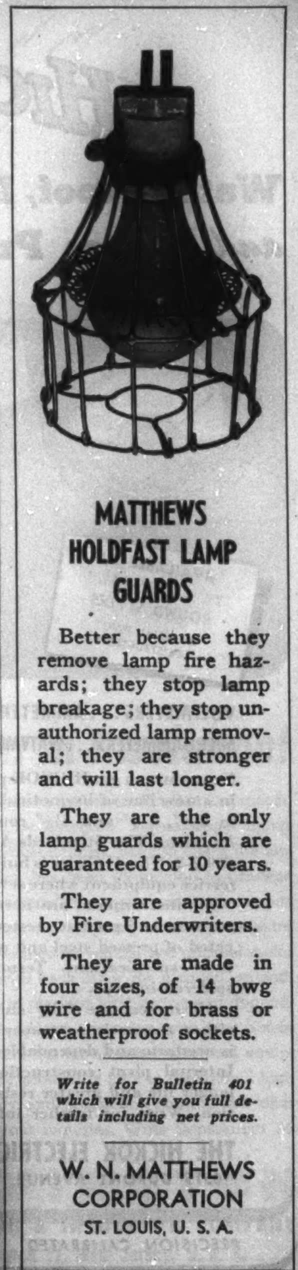

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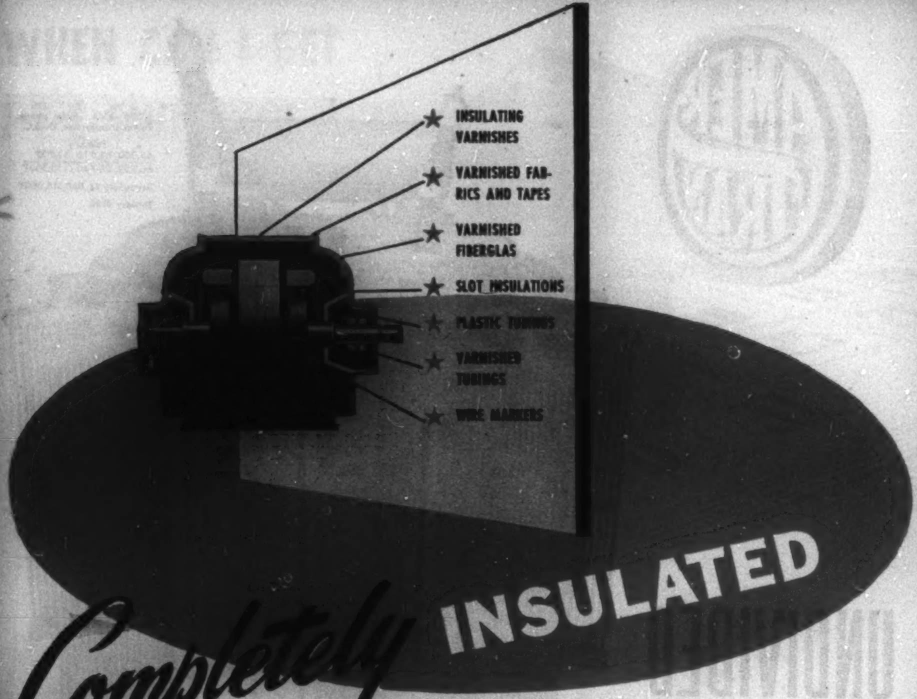

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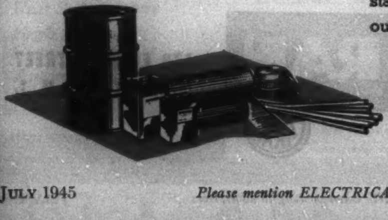

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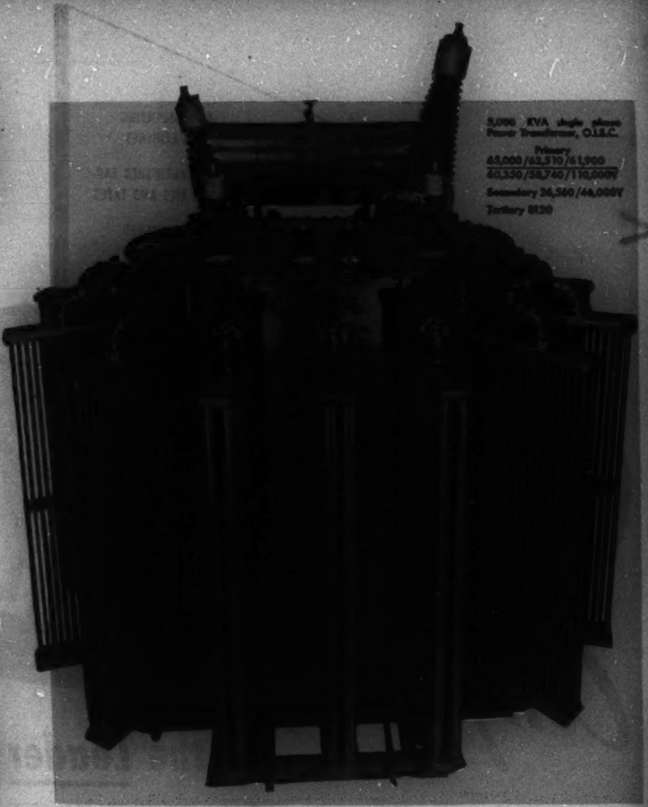

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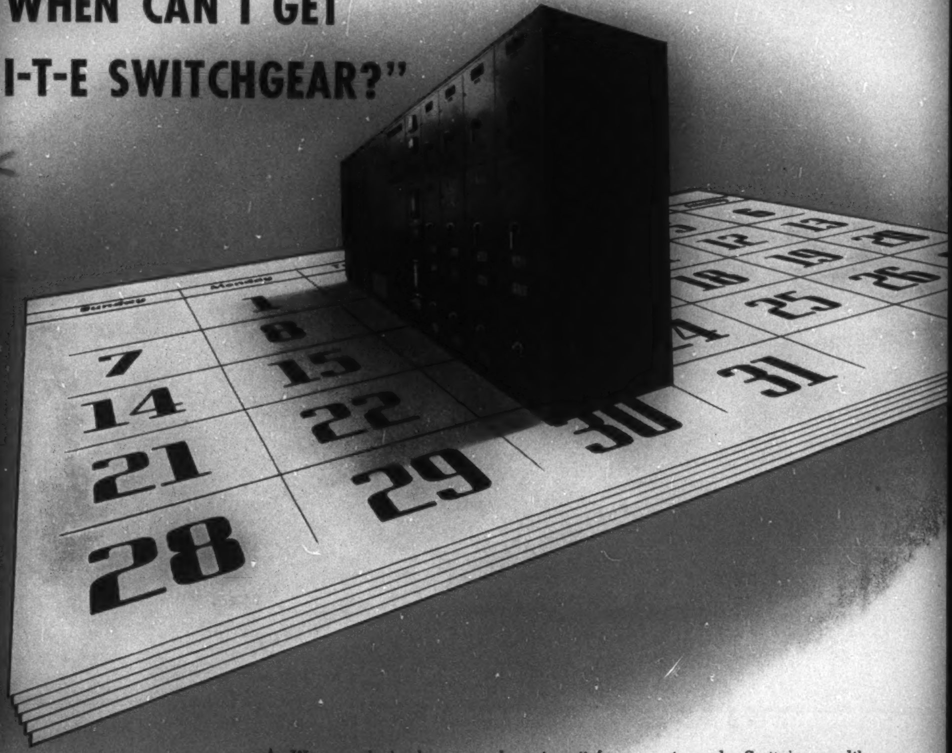
"WHEN CAN I GET I-T-E SWITCHGEAR?"



☆ Wear and obsolescence do not wait for wars to end. Switchgear, like most everything else, has long been heavily loaded, often held together by a string and a prayer. Consequently the question of delivery of much-needed Switchgear . . . for replacement and for additional capacity . . . is of vital importance.

The answer can not yet be given in terms of calendar days; while the priority system remains in effect, delivery of I-T-E Switchgear will be determined by government control. Military demands, however, are easing and switchgear is gradually becoming available to additional industries.

Not waiting for the removal of controls, several I-T-E customers have already placed non-priority orders for I-T-E Switchgear. These will be manufactured . . . without lost motion and without delay . . . as soon as priorities are lifted. If you are interested in getting under way at the first possible moment, write us regarding your plans. I-T-E engineers will be glad to assist you in placing a "first-come—first-served" order for I-T-E Air Switchgear. The I-T-E Circuit Breaker Co., 19th & Hamilton Sts., Philadelphia 30, Pa.

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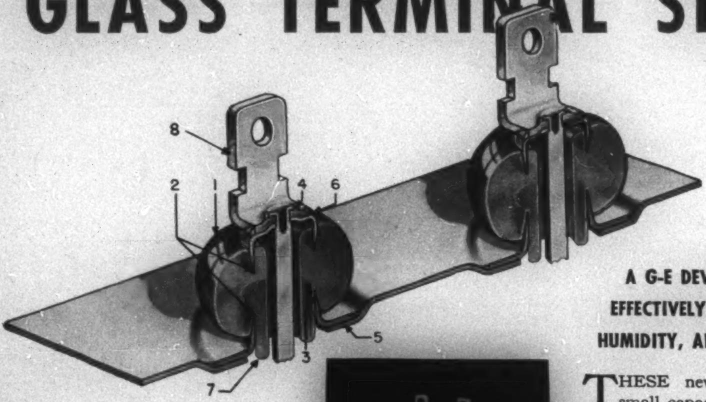
Automatic Reclosing Circuit Breakers

I-T-E AIR SWITCHGEAR

Announcing

a distinct advance in small-capacitor design

GLASS TERMINAL SEALS



1 Exceptionally stable, low-expansion glass, practically unaffected by weathering, microörganisms, and thermal shock.

2 Metal sections, made of corrosion-resistant nickel steel, are sealed into opposite ends of the glass by a heating process in which the oxide on the steel is fused into the glass to form an impervious bond between the two.

3 Metal sections are tapered to keep stresses in the glass at negligible values under thermal-shock conditions. The seal is designed to pass American War Standard thermocycle tests with a wide margin of safety.

4 High mechanical strength is provided because terminal is *riveted* to top metal section, and,

5 Terminal seal is brazed to capacitor cover.

6 All joints are hermetically sealed. *None relies* on soft solder for mechanical strength.

7 Adequate electrical clearance between lead and case is maintained by the glass skirt.

8 Easy attachment of external leads is assured by making terminal of *solder-dipped* brass.

G-E Pyranol capacitor (case style CP-62) equipped with glass terminal seals

A G-E DEVELOPMENT THAT EFFECTIVELY RESISTS FUNGUS, HUMIDITY, AND THERMAL SHOCK

THESE new terminal seals for small capacitors are based on the many glass-to-metal seal developments pioneered by our Research Laboratory and Lamp Department over a period of years. The seal is similar, in many respects, to the seals being used so successfully to maintain a high vacuum indefinitely in G-E sealed-beam headlamps, millions of which are now in use.

This development makes possible a capacitor seal that will withstand the most severe operating conditions—sudden or prolonged heat or cold, high altitude, rain, humidity, fungus, and microscopic animal infiltration. It differs from most glass-to-metal seals in that it does not *rely* on soft solder for mechanical strength, nor on matched coefficients of expansion of glass and metal to resist thermal shock.

G-E capacitors equipped with glass terminal seals are, at present, available in case styles CP-60, -62, and -64 in all ratings covered by proposed specification JAN-C-25, for use in combat communications equipment where severe operating conditions may be encountered. Ask for Bulletin GEA-4424 for complete information. *General Electric Company, Schenectady 5, N. Y.*

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